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ABSTRACT

This publication is the second in a series of three texts for a diesel mechanics curriculum. Its purpose is to teach the concepts related to electricity and circuitry in a diesel trade. The text contains nine units. Each instructional unit includes some or all of these basic components: unit and specific (performance) objectives, suggested activities for teachers and students, information sheets, transparency masters, assignment sheets, answers to assignment sheets, job sheets, pencil-paper and performance tests, and answers to tests. Introductory materials include description of unit components, instructional/task analysis (psychomotor and cognitive skills to be learned), listing of needed tools and equipment, and reference list. Unit titles are Introduction to Electrical Systems, Electrical Circuits, Electrical Indicator Circuits, Storage Batteries, Starting Circuits, Ignition Circuits, Generator Charging Circuits, Alternator Charging Circuits, and Emergency Shut-Down Circuits. (YLB)

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DIESEL MECHANICS: ELECTRICAL SYSTEMS

by

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revised by

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Developed by the

Mid-America Vocational Curriculum Consortium, Inc.

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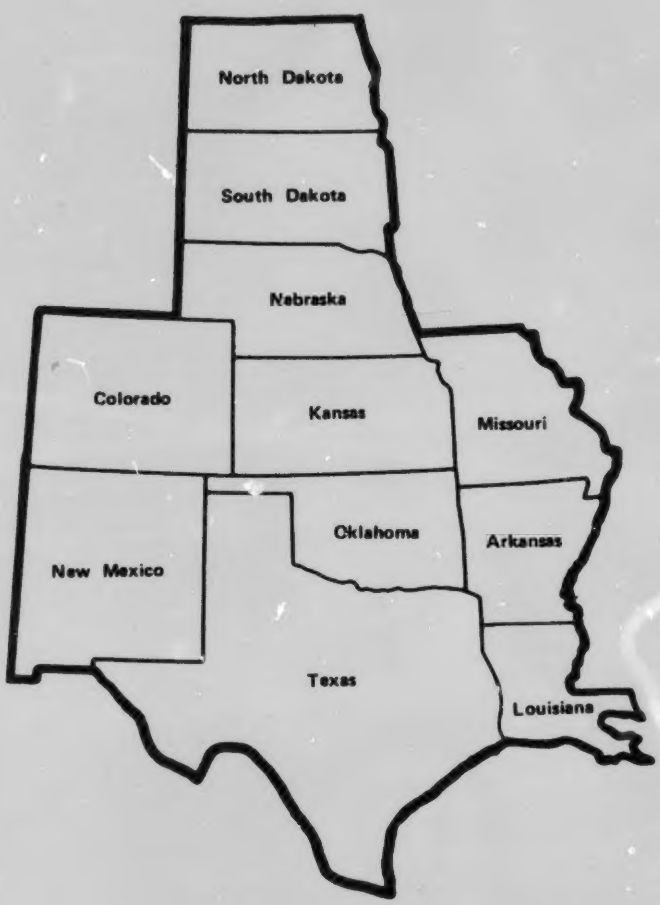
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FOREWORD

The Mid-America Vocational Curriculum Consortium (MAVCC) was organized for the purpose of developing instructional materials for its eleven member states. All member states participate in establishing annual development priorities, and the need for curriculum in diesel mechanics truly reflects regional needs.

Diesel Engine Mechanics was originally produced in 1977. Since that time, technology as related to equipment and methods has changed. To keep abreast of these changes, MAVCC has revised this book into three shorter publications.

Diesel Mechanics: Electrical Systems is the second publication of a series of three texts dedicated to a diesel mechanics curriculum. Although it can be taught as a single text, it is designed to be used in conjunction with *Diesel Mechanics: Fuel Systems* and *Diesel Mechanics: Fundamentals* to provide continuity in student training. Other MAVCC publications entitled *Hydraulics* and *Power Trains* will broaden the scope of the diesel training. Another use of this book is to supplement the training of an auto mechanics student who may later be working on diesel powered automobiles. It is hoped that this effort will provide industry with truly well trained technicians for the world of diesel and the varied skills it demands.

The success of this publication is due, in large part, to the capabilities of the personnel who worked with its development. The technical writers have numerous years of industry as well as teaching experience. Assisting them in their efforts were representatives of each of the member states who brought with them technical expertise and the experience related to the classroom and to the trade. To assure that the materials would parallel the industry environment and be accepted as a transportable basic teaching tool, organizations and industry representatives were involved in the developmental phases of the manual. Appreciation is extended to them for their valuable contributions to the manual.

Instructional materials in this publication are written in terms of student performance using measurable objectives. This is an innovative approach to teaching that accents and augments the teaching/learning process. Criterion referenced evaluation instruments are provided for uniform measurement of student progress. In addition to evaluating recall information, teachers are encouraged to evaluate the other areas including process and product as indicated at the end of each instructional unit.

It is the sincere belief of the MAVCC personnel and all those members who served on the committees that this publication will allow the students to become better prepared and more effective members of the work force.

Merle Rudebusch, Chairman
Board of Directors
Mid-America Vocational
Curriculum Consortium

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PREFACE

Both the development and revision of instructional materials in diesel mechanics have been rewarding efforts because of the talented people who planned and wrote the materials. From the team of teachers, industry representatives, and trade and industrial staff members whose combined years of experience in the diesel trade total over 260 years has come a series of texts which should offer diesel mechanics students an excellent opportunity for learning required skills.

The title of this second book of the series, *Diesel Mechanics: Electrical Systems* indicates that this book is dedicated to teaching the concepts related to electricity and circuitry in a diesel trade. Naturally, this book is designed to be used with other MAVCC books related to diesel. These include *Diesel Mechanics: Fuel Systems, Diesel Mechanics: Fundamentals, Power Trains,* and *Hydraulics.*

As complex as some mechanical activities are, the MAVCC format presents the procedures in logically ordered objectives that facilitate a comfortable learning rate. The format also frees the instructor to concentrate on reinforcing classroom instruction with films, field trips, and other activities that serve to maintain student interest at a high level and motivate students to learn and do.

Despite careful planning and editing, we know that the text may perhaps contain a typographical error or two. Letting us know when you find such items will be a great help in improving the product before reprint time. But most of all, your input about the major elements in the book will be valuable help for changing or adding objectives when the materials are again revised and updated.

We respond to your suggestions, and we hope the quality of the MAVCC materials related to diesel will serve a positive role in the classroom and provide industry with the skilled people that are so needed.

Ann Benson
Executive Director
Mid-America Vocational
Curriculum Consortium

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ACKNOWLEDGEMENTS

Appreciation is extended to those individuals who contributed their time and talents to the development of *Diesel Mechanics: Electrical Systems*.

The contents of this publication were planned and reviewed by:

Mid-America Vocational Curriculum Consortium Committee

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Thanks are extended to Ron Simmons for representing teacher education on this committee and to Donnie Tuminello for representing state supervisory personnel.

Special thanks are extended to Harlan Gjoraas of the Kearns Machinery Company and Doug MacDonald of Technical Systems, Inc. for their representation of industry on the committee and to the numerous other companies who provided references and technical materials.

Gratitude is expressed to Jane Huston and P.J. Colbert for editing and to the Graphics Division of the Oklahoma State Department of Vocational and Technical Education for typing and art work.

The printing staff of the Oklahoma State Department of Vocational and Technical Education is deserving of much credit for printing this publication.

Special appreciation is extended to those who served on the original advisory committee representing the many MAVCC states.

USE OF THIS PUBLICATION

Instructional Units

Diesel Mechanics: Electrical Systems includes nine units. Each instructional unit includes some or all of the basic components of a unit of instruction: performance objectives, suggested activities for teachers and students, information sheets, assignment sheets, job sheets, visual aids, tests, and answers to the test. Units are planned for more than one lesson or class period of instruction.

Careful study of each instructional unit by the teacher will help to determine:

A. The amount of material that can be covered in each class period
B. The skills which must be demonstrated
    1. Supplies needed
    2. Equipment needed
    3. Amount of practice needed
    4. Amount of class time needed for demonstrations
C. Supplementary materials such as pamphlets or filmstrips that must be ordered
D. Resource people who must be contacted

Objectives

Each unit of instruction is based on performance objectives. These objectives state the goals of the course, thus providing a sense of direction and accomplishment for the student.

Performance objectives are stated in two forms: unit objectives, stating the subject matter to be covered in a unit of instruction; and specific objectives, stating the student performance necessary to reach the unit objective.

Since the objectives of the unit provide direction for the teaching-learning process, it is important for the teacher and students to have a common understanding of the intent of the objectives. A limited number of performance terms have been used in the objectives for this curriculum to assist in promoting the effectiveness of the communication among all individuals using the materials.

Following is a list of performance terms and their synonyms which may have been used in this material:

Name	Identify	Describe
Label	Select	Define
List in writing	Mark	Discuss in writing
List orally	Point out	Discuss orally
Letter	Pick out	Interpret
Record	Choose	Tell how
Repeat	Locate	Tell what
Give	Label	Explain

Order
Arrange
Sequence
List in order
Classify
Divide
Isolate
Sort

Distinguish
Discriminate
Differentiate

Construct
Draw
Make
Build
Design
Formulate
Reproduce
Transcribe
Reduce
Increase
Figure

Demonstrate
Show your work
Show procedure
Perform an experiment
Perform the steps
Operate
Remove
Replace
Turn off/on
(Dis) assemble
(Dis) connect

Additional Terms Used
Evaluate
Complete
Analyze
Calculate
Estimate
Plan
Observe
Compare
Determine
Perform

Prepare
Make
Read
Tell
Teach
Converse
Lead
State
Write

Reading of the objectives by the student should be followed by a class discussion to answer any questions concerning performance requirements for each instructional unit.

Teachers should feel free to add objectives which will fit the material to the needs of the students and community. When teachers add objectives, they should remember to supply the needed information, assignment and/or job sheets, and criterion tests.

Suggested Activities for the Instructor:

Each unit of instruction has a suggested activities sheet outlining steps to follow in accomplishing specific objectives. Duties of instructors will vary according to the particular unit; however, for best use of the material they should include the following: provide students with objective sheet, information sheet, assignment sheets, and job sheets; preview filmstrips, make transparencies, and arrange for resource materials and people; discuss unit and specific objectives and information sheet; give test. Teachers are encouraged to use any additional instructional activities and teaching methods to aid students in accomplishing the objectives.

Information Sheets

Information sheets provide content essential for meeting the cognitive (knowledge) objectives in the unit. The teacher will find that the information sheets serve as an excellent guide for presenting the background knowledge necessary to develop the skill specified in the unit objective.

Students should read the information sheets before the information is discussed in class. Students may take additional notes on the information sheets.

Transparency Masters

Transparency masters provide information in a special way. The students may see as well as hear the material being presented, thus reinforcing the learning process. Transparencies may present new information or they may reinforce information presented in the information sheets. They are particularly effective when identification is necessary.

Transparencies should be made and placed in the notebook where they will be immediately available for use. Transparencies direct the class's attention to the topic of discussion. They should be left on the screen only when topics shown are under discussion.

Job Sheets

Job sheets are an important segment of each unit. The instructor should be able to and in most situations should demonstrate the skills outlined in the job sheets. Procedures outlined in the job sheets give direction to the skill being taught and allow both student and teacher to check student progress toward the accomplishment of the skill. Job sheets provide a ready outline for students to follow if they have missed a demonstration. Job sheets also furnish potential employers with a picture of the skills being taught and the performances which might reasonably be expected from a person who has had this training.

Assignment Sheets

Assignment sheets give direction to study and furnish practice for paper and pencil activities to develop the knowledges which are necessary prerequisites to skill development. These may be given to the student for completion in class or used for homework assignments. Answer sheets are provided which may be used by the student and/or teacher for checking student progress.

Test and Evaluation

Paper-pencil and performance tests have been constructed to measure student achievement of each objective listed in the unit of instruction. Individual test items may be pulled out and used as a short test to determine student achievement of a particular objective. This kind of testing may be used as a daily quiz and will help the teacher spot difficulties being encountered by students in their efforts to accomplish the unit objective. Test items for objectives added by the teacher should be constructed and added to the test.

Test Answers

Test answers are provided for each unit. These may be used by the teacher and/or student for checking student achievement of the objectives.

DIESEL MECHANICS: ELECTRICAL SYSTEMS

INSTRUCTIONAL/TASK ANALYSIS

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)	RELATED INFORMATION: What the Worker Should Know (Cognitive)

UNIT I: INTRODUCTION TO ELECTRICAL SYSTEMS

1. Terms and definitions
2. Safety practices
3. Particles found in an atom
4. Nature of electron flow
5. Sources of electricity related to diesel engines
6. Parts of a basic circuit
7. Conductors and insulators in electron theory
8. Basic circuit terms
9. Causes of resistance
10. Basic electrical schematic symbols
11. Letter designations used in Ohm's Law
12. Ohm's Law
13. Types of electrical circuits
14. Rules for series and parallel circuits
15. Factors affecting resistance in a conductor
16. Characteristics of magnetism
17. Relationship between electricity and magnetism
18. Principle of electromagnetic induction
19. Magnitude of induced voltage

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)	RELATED INFORMATION: What the Worker Should Know (Cognitive)
	20. Types of electric current
	21. Direct and alternating current
	22. Instruments use in checking electrical circuits
23. Solve problems using Ohm's Law	

UNIT II: ELECTRICAL CIRCUITS

JOB TRAINING	RELATED INFORMATION
	1. Terms and definitions
	2. Types of connectors
	3. Symbols used in circuits
	4. Checking an electrical circuit
	5. Troubleshooting an electrical system
	6. Types of test equipment
7. Check voltage	
8. Check continuity	

UNIT III: ELECTRICAL INDICATOR CIRCUITS

JOB TRAINING	RELATED INFORMATION
	1. Terms and definitions
	2. Types of gauges
	3. Parts in a gauge circuit
	4. Testing procedures for an ammeter gauge
	5. Testing a fuel level gauge
	6. Testing a temperature gauge
	7. Procedures for testing a voltmeter
8. Test the fuel level gauge sending unit	
9. Check for a grounded circuit	

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)	RELATED INFORMATION: What the Worker Should Know (Cognitive)
UNIT IV: STORAGE BATTERIES	
	1. Terms and definitions
	2. Functions of a battery
	3. Parts of a battery
	4. Process by which a battery converts chemical energy into electrical energy
	5. Battery rating
	6. Care and maintenance of batteries
	7. Characteristics of "service free" batteries
8. Clean and service a battery	
9. Remove and replace a battery	
10. Measure specific gravity of a battery's electrolyte with a hydrometer	
11. Load test a battery	
12. Charge test a battery for three minutes	
UNIT V: STARTING CIRCUITS	
	1. Terms and definitions
	2. Purpose of a starting circuit
	3. Parts in a starting circuit
	4. Parts of a starting motor
	5. Operation of a starting motor
	6. Types of starter field circuits
	7. Counter electromotive force
	8. Types of switches
	9. Engaging starter drives

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)	RELATED INFORMATION: What the Worker Should Know (Cognitive)
	10. Types of electromagnetic or lever shift drives
11. Remove and replace a starter	
12. Disassemble, test, and reassemble a starter	
13. Test starter circuit	
14. Recondition starting motor armature	
15. Check voltage drop in a starter circuit	

UNIT VI: IGNITION CIRCUITS

	1. Terms and definitions
	2. Purpose of an ignition circuit
	3. Components of an ignition circuit
	4. Primary and secondary ignition circuit components
	5. Components of a distributor
	6. Operation of an ignition circuit
	7. Transistorized and capacitive discharge ignition systems
	8. Components of an electronic ignition system
9. Remove and install a distributor	
10. Remove and replace contact points and condenser	
11. Adjust dwell on an externally adjustable distributor	
12. Check and set ignition timing	
13. Remove, service, and replace spark plugs	

JOB TRAINING: What the
Worker Should Be Able to Do
(Psychomotor)

RELATED INFORMATION: What
the Worker Should Know
(Cognitive)

UNIT VII: GENERATOR CHARGING CIRCUITS

1. Terms and definitions
2. Purpose of a generator charging circuit
3. Kinds of charging cicuits
4. Components in the DC charging circuit
5. Parts of a generator
6. Stages of a charging circuit
7. Flow of current
8. Conversion of AC to DC
9. Generator field circuits
10. Generator regulator components
11. Types of generators
12. Types of electrical failure
13. Reverse polarity
14. Test generator output
15. Remove and replace a generator
16. Disassemble, test, and reassemble a generator
17. Test and adjust a regulator unit

UNIT VIII: ALTERNATOR CHARGING CIRCUITS

1. Terms and definitions
2. Purpose of the alternator charging circuit
3. Components of the alternator charging circuit
4. Parts of an alternator

JOB TRAINING: What the Worker Should Be Able to Do
(Psychomotor)

RELATED INFORMATION: What the Worker Should Know
(Cognitive)

5. Difference between an alternator and generator
6. Construction of stator windings
7. Brushless alternators
8. Parts of a transistorized regulator
9. Safety rules

10. Test the alternator charging circuit and regulator
11. Remove and replace an alternator
12. Disassemble, test, and reassemble an alternator
13. Test and repair a transistorized regulator
14. Test an alternator with an I.C. regulator

UNIT IX: EMERGENCY SHUT-DOWN CIRCUITS

1. Terms and definitions
2. Characteristics of a temperature controlled system
3. Shut-off solenoids
4. Overspeed contactor switch
5. Pressure switch
6. Oil pressure and water temperature shut-off switches
7. Oil pressure contactor switch
8. Operation of an alarm system

9. Troubleshoot the contactor switch for water temperature
10. Test a shut-off and alarm system

TOOLS AND MATERIALS

(NOTE: This is an alphabetized list of tools and materials needed to complete the job sheets in this text.)

Adjustable, fast rate battery charger
Air gap gauge
Alternator diode removal equipment
Alternator pulley removal tools
Alternator test equipment
Ammeter
Appropriate conductors
Appropriate service manual
Auxiliary starter button
Baking soda and water solution
Ball bearing grease
Basic hand tool set
Battery
Battery anti-corrosion paste
Battery cable clamp removal tool
Battery cable puller
Battery cable spreader
Battery capacitor tester
Battery clamp puller
Battery lift strap
Battery pliers
Battery post and cable cleaner
Battery post cleaning tool
Belt tension gauge
Bristle brush
Cap
Carbonpile resistor
Chalk
Circuit tester
Clean shop towels
Combination end wrenches (3/8" - 3/4", 7/16" - 9/16")
Contactor switch
Container of clean water
Continuity light
Distributor cam lubricant
Drill motor
Dwell meter
Engine
Extensions, 3" - 6" - 10" by 3/8" drive
Feeler gauges, .010 - 0.25
Generator
Generator pulley puller
Growler
Hacksaw blade
Hammer
Heating torch
Hex contact point adjusting tool

Hose assemblies (2)
Hydrometer
Ignition wrench set, small
Jumper leads
Jumper wire, 12" with alligator clips
Manufacturer's specifications
Metal block for heat sink
Metal pan
Needle nose pliers
1/4 ohm fixed resistor
Ohmmeter
Pipe nipple, 1/8" x 2"
Pipe nipples, 1/8" x 3.5" (2)
Pipe tap, 1/2" NPT
Pliers (2 pair)
Point alignment tools
Point file, small
Pressure gauge, 0-50 p.s.i.
Ratchet, 3/8" drive
Rubber apron
Rubber gloves
Safety glasses
Screwdriver
Shut-off cock fittings
Spark plug socket, 3/8" drive
Spark plug socket wrench
Special distributor wrenches, as required
Special tool for turning commutators or a lathe
Special tool for undercutting commutator or hacksaw blade
Spring tension gauge
Starting motor
Suitable armature growler and test light
Switch
Tachometer
Tees, various sizes (3)
Test lamp
Thermometer, 0-220°F
Torque wrench
Variable resistor
Vehicle
Voltmeter
Wire brush
Wood block, small

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(Note: This is an alphabetized list of references used in completing this text.)

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INTRODUCTION TO ELECTRICAL SYSTEMS
UNIT I

UNIT OBJECTIVE

After completion of this unit, the student should be able to define electricity according to the atomic theory and solve problems using Ohm's Law. The student should also be able to identify three types of electrical circuits and distinguish between direct and alternating current. This knowledge will be evidenced by correctly performing the procedures outlined in the assignment sheet and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to electrical systems with their correct definitions.
2. Select true statements concerning safety practices dealing with electrical systems.
3. Name two particles found in an atom.
4. Explain the nature of electron flow.
5. Define electricity according to the atomic theory.
6. Identify three sources of electricity related to diesel engines.
7. Name three parts of a basic circuit.
8. Distinguish between a good conductor and a good insulator in electron theory.
9. Distinguish between good conductors and insulators of electricity.
10. Explain why copper is widely used as a conductor.
11. Match the basic circuit terms with their units of measure.
12. List two causes of resistance to the flow of current (electrons).
13. Match the basic electrical schematic symbols with their correct names.
14. Match the letter designations used in Ohm's Law with their correct terms.
15. Draw Ohm's Law formula in triangle expression.
16. State Ohm's Law in letter formula for calculating voltage, current, and resistance.

17. Identify three types of electrical circuits.

18. List three rules for series circuits.

19. List three rules for parallel circuits.

20. Name three factors affecting resistance in a conductor.

21. Select the characteristics of magnetism.

22. Complete a list of ways an iron bar may be magnetized.

23. Select true statements concerning the relationship between electricity and magnetism.

24. Select true statements concerning the principle of electromagnetic induction.

25. List three ways in which a voltage may be induced by electromagnetic induction.

26. List three factors that determine the magnitude of induced voltage.

27. Name two types of electric current.

28. Distinguish between direct and alternating current.

29. Name four instruments used in checking electrical circuits.

30. Solve problems using Ohm's Law.

INTRODUCTION TO ELECTRICAL SYSTEMS
UNIT I

SUGGESTED ACTIVITIES

I. Provide student with objective sheet.

II. Provide student with information and assignment sheets.

III. Make transparencies.

IV. Discuss unit and specific objectives.

V. Discuss information and assignment sheets.

VI. Demonstrate magnetic lines of force by using iron filings and a conductor.

VII. Assign students to construct a series and a parallel circuit.

VIII. Demonstrate safety practices concerning electricity.

IX. Demonstrate how to make an electromagnet using 5' of copper wire, a soft iron bar, and a 1.5 volt battery.

X. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

  A. Objective sheet

  B. Information sheet

  C. Transparency masters

    1. TM 1--Structure of Atoms

    2. TM 2--Electron Flow

    3. TM 3--Sources of Electricity

    4. TM 4--Ohm's Law in Triangle Expression

    5. TM 5--Ohm's Law in Letter Designation

    6. TM 6--Types of Electrical Circuits

    7. TM 7--Series Circuit Rules

8. TM 8--Parallel Circuit Rules
9. TM 9--Magnetism and Field of Force
10. TM 10--Electricity and Magnetism Relationship
11. TM 11--Measuring Instruments

D. Assignment Sheet #1--Solve Problems Using Ohm's Law

E. Answers to assignment sheet

F. Test

G. Answers to test

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A. *Fundamentals of Service: Electrical Systems.* Fourth Edition. Moline, IL: Deere and Company, 1979.

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INTRODUCTION TO ELECTRICAL SYSTEMS
UNIT I

INFORMATION SHEET

I. Terms and definitions

A. Atom--Smallest unit of all matter

B. Electrons--Particles with a negative charge in orbit around a core of protons

C. Protons--Particles with a positive charge that make up the nucleus of the atom

D. Current--Flow of electrons through a conductor, measured in amperes

E. Conductor--Any material that permits passage of electric current

F. Semiconductor--An element which has four electrons in outer ring; used to make diodes and transistors; not a good conductor or insulator

G. Voltage--Potential difference that causes flow of current

H. Resistance--Opposition to current flow in a conductor

I. Insulator--Material with an extremely high resistance to current flow

J. Electrochemical--Stored chemical energy which can be converted to electrical current

K. Electromagnetic--Electricity generated by cutting the magnetic lines of force (field) around a magnet

L. Thermoelectric--Electricity generated by heat

M. Thermocouple--Thermoelectric device used to measure temperature accurately

N. Electromagnetic induction--Inducing voltage in a conductor that moves across a magnetic field

O. Mutual induction--Occurs when changing current in one coil induces voltage in a second coil

P. Self induction--Voltage which occurs in a coil when there is a change of current

Q. Generator (direct current)--Voltage and current produced by moving conductors across a stationary magnetic field

R. Alternator (alternating current generator)--Voltage and current produced by a rotating magnetic field cutting across stationary conductors

S. Work--Force times distance

INFORMATION SHEET

- T. Power--Rate of doing work
- U. Watt--Electrical measurement of rate of doing work

  (NOTE: 746 watts = 1 horsepower.)
- V. Emf--Electromotive force or voltage
- W. Counter emf--Voltage induced in a conductor which is moving through a magnetic field in opposition to the source of voltage

  (NOTE: This is a generator action developed in every motor.)
- X. Cycle (hertz)--One complete reversal of an alternating current from positive to negative and back to the starting point
- Y. Parallel circuit--Current has more than one path to take
- Z. Series circuit--Current has only one path it can take
- AA. Series-parallel circuit--A circuit consisting of both series and parallel components
- BB. Safety--State of being free from risk

II. Safety practices dealing with electrical systems

- A. When working on electrical system that is connected to the battery, remove all jewelry
- B. When disconnecting battery cables, remove the ground cable first
- C. If you are using an ohmmeter, disconnect the battery
- D. Never leave the ignition switch on when installing a distributor
- E. Never ground the output terminal of the alternator
- F. Never lay any conductor across the battery terminals
- G. When replacing an electrical component, always disconnect the battery first
- H. Never apply full battery voltage to the fuel tank sending unit
- I. When using jumper cables, always connect ground to the frame or engine
- J. When using a battery charger, make your connections before plugging the charger in
- K. When adding accessories, make sure they match the vehicle's ground
- L. When replacing a conductor, always use the same size (gauge) conductor

INFORMATION SHEET

M. When adding accessories, be sure to not exceed the charging system output

(NOTE: The charging system should have an output of 10% above total current draw.)

III. Particles in an atom (Transparency 1)

A. Electron

B. Proton

(NOTE: These are the particles involved in the electron theory.)

IV. Nature of electron flow--When acted upon by a source such as friction, electrons in the outer ring or orbit break away to other atoms (Transparency 2)

Example: When a rubber rod is rubbed with wool, electrons are removed from the wool and collected on the rod. The wool now has too few electrons and is positively charged. The rod has too many electrons and is negatively charged.

V. Electricity--The flow of electrons from atom to atom in a conductor (Transparency 2)

VI. Sources of electricity related to diesel engines (Transparency 3)

A. Thermoelectric

B. Electrochemical

C. Electromagnetic

VII. Parts of a circuit

A. Voltage

Example: Battery

B. Resistor

Example: Light bulb

C. Conductor

Example: Copper wire

VIII. Conductor and insulator difference

A. Conductor has less than four electrons in outer ring

B. Insulator has more than four electrons in outer ring

INFORMATION SHEET

IX. Conductors and insulators of electricity

A. Conductors

1. Silver

   (NOTE: Silver has the least resistance to current flow.)

2. Copper
3. Gold
4. Aluminum
5. Tungsten
6. Zinc
7. Brass
8. Platinum
9. Iron
10. Nickel
11. Tin
12. Steel
13. Lead
14. Mercury
15. Nichrome

    (NOTE: Nichrome has the highest resistance to current flow.)

B. Insulators

1. Glass
2. Rubber
3. Plastic
4. Wood
5. Ceramic
6. Mica

X. Copper as a conductor--Copper has only one electron in outer ring and is comparatively cheaper than other metals which may have the same properties (Transparency 1)

INFORMATION SHEET

XI. Circuit terms and units of measure

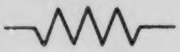
- A. Current--Amperes
- B. Voltage--Volts
- C. Resistance--Ohms

XII. Causes of resistance

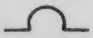
- A. Core of atoms (protons) attracts orbiting electrons, which resist their removal
- B. Collision of countless electrons as they move

XIII. Basic electrical schematic symbols

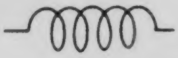
- A. Resistance or load



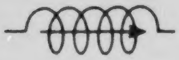
- B. Ohm's of resistance



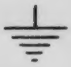
- C. Inductor (coil)



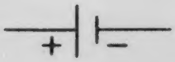
- D. Inductor (solenoid)



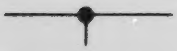
- E. Ground



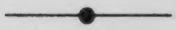
- F. Battery



- G. Connection

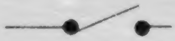


- H. Terminal

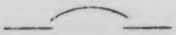


INFORMATION SHEET

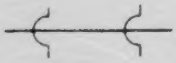
I. Switch (open)



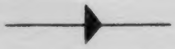
J. Circuit breaker



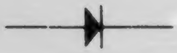
K. Crossover



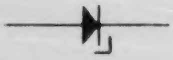
L. Direction of current



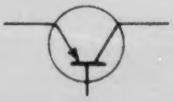
M. Diode (one-way)



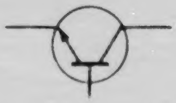
N. Zener diode



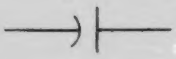
O. Transistor (PNP type)



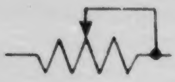
P. Transistor (NPN type)



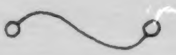
Q. Capacitor



R. Variable resistor



S. Fuse



XIV. Letter designations and terms

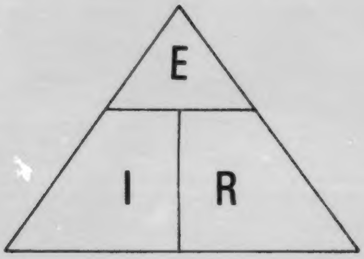
A. E--Electromotive force in volts

B. I--Intensity (current) in amps

C. R--Resistance in ohms

INFORMATION SHEET

XV. Ohm's Law formula in triangle expression (Transparency 4)



(NOTE: E.I.R. formula reminder is the phrase "Even I Remember.")

XVI. Ohm's Law in letter formula (Transparency 5)

A. E = I x R or Volts = Amps x Ohms

B. I = E/R or Amps = Volts÷Ohms

C. R = E/I or Ohms = Volts÷Amps

XVII. Types of electrical circuits (Transparency 6)

A. Series

B. Parallel

C. Series-parallel

XVIII. Rules for series circuits (Transparency 7)

A. Current through each resistor is the same

B. Voltage drops across each resistor will be different if the resistance values are different

C. Sum of the voltage drops equals the source voltage

XIX. Rules for parallel circuits (Transparency 8)

A. Voltage across each resistor is the same

B. Current through each resistor will be different if the resistance values are different

C. Sum of the separate currents equals the total circuit current

INFORMATION SHEET

XX. Factors affecting resistance in a conductor

   A. Length of wire

   B. Diameter of wire

   C. Temperature of wire

XXI. Characteristics of magnetism (Transparency 9)

   A. Every magnet has a north and south pole

   B. Unlike poles attract and like poles repel

   C. Every magnet has a field of force surrounding it

   D. Magnetic materials are acted upon when located in a field of force

   E. An unmagnetized piece of iron can become a magnet through the principle of electromagnetic induction

XXII. Magnetizing an iron bar

   A. Stroke an iron bar with another bar which has been magnetized

   B. Place an iron bar in a strong magnetic field

   (NOTE: Soft metals will not retain much magnetism when withdrawn from the magnetic field.)

XXIII. Relationship between electricity and magnetism (Transparency 10)

   A. Current passed through a wire (conductor) creates a magnetic field around the wire

   B. Magnetic lines have direction and change direction when the current flow changes from one direction to another

   (NOTE: The Right Hand Rule for a straight conductor can be used to find the direction of the lines of force around the wire. To apply the rule, grasp the wire with the thumb extended in the direction of conventional current flow (positive to negative); the fingers will then point in the direction in which the lines of force surround the conductor. These lines of force are always at right angles to the conductor.)

   C. Two conductors on an armature, carrying current in opposite directions, create a strong and weak field on opposite sides causing conductors to move apart or armature to rotate

   (NOTE: The downward movement or rotation is caused by current flowing in the conductor. This is the principle by which a cranking motor operates.)

INFORMATION SHEET

XXIV. Electromagnetic induction

- A. Conductor moving across a magnetic field will have a voltage (emf) induced in it
- B. Voltage polarity and the current flow direction are determined by the direction of wire movement and direction of the lines of force

  (NOTE: The conductor can move or the magnetic field can move.)

XXV. Ways to induce voltage by electromagnetic induction

- A. Generated voltage by relative motion

  Examples: Generators and alternators

- B. Self induction voltage created by a change of current in the conductor

  Example: Primary of ignition coils

- C. Mutual induction voltage which occurs when changing current in one coil induces voltage in a second coil

  Example: Two windings of ignition coils

XXVI. Factors that determine the magnitude of induced voltage

- A. Strength of the magnetic field
- B. Speed at which lines of force are cutting across the conductor
- C. Number of conductors that are cutting across the lines of force

XXVII. Types of electric current

- A. Direct
- B. Alternating

XXVIII. Direct and alternating current

- A. Direct current
  - 1. Supplied by
    - a. Generator
    - b. Battery
      - 1) Dry cell
      - 2) Wet cell

INFORMATION SHEET

2. Flows in one direction only

3. Abbreviated as DC

B. Alternating current

1. Supplied by an alternating current generator (alternator)

2. Flows in one direction then reverses and flows in the opposite direction

3. Abbreviated as AC

XXIX. Instruments used in checking electrical circuits (Transparency 11)

A. Ammeter

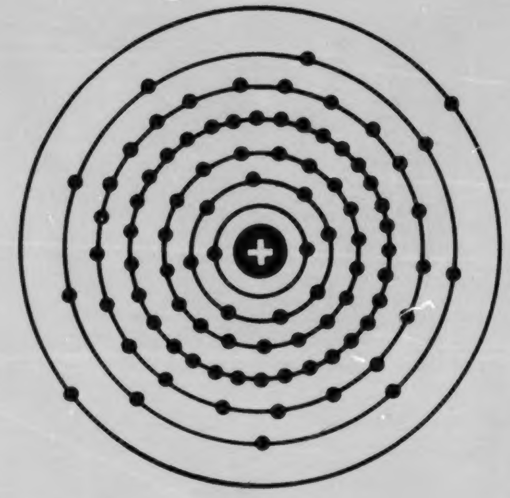
B. Voltmeter

C. Ohmmeter

D. Wattmeter

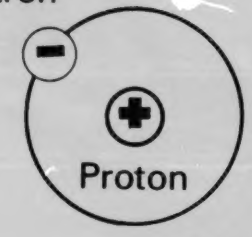
(NOTE: Modern testers often combine the voltmeter, ammeter, and ohmmeter in one test unit, such as a battery-starter tester.)

Structure of Atoms



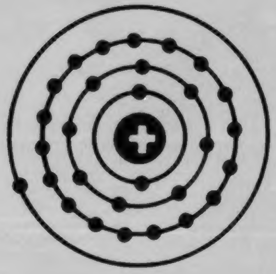
Uranium Atom

92 Electrons
92 Protons



Hydrogen Atom

1 Electron
1 Proton

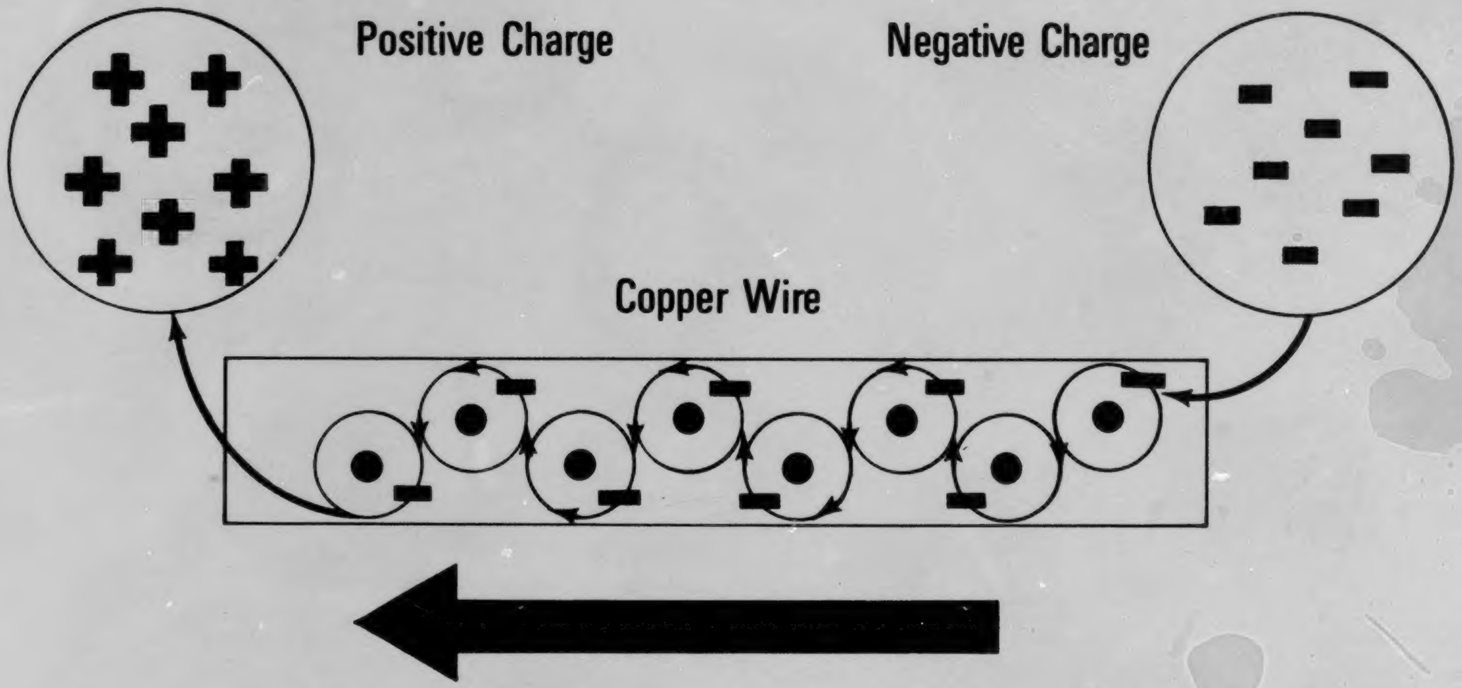


Copper Atom

29 Electrons
29 Protons

NOTE: Count the Number of Electrons in the Outer Ring of the Atom.

Electron Flow



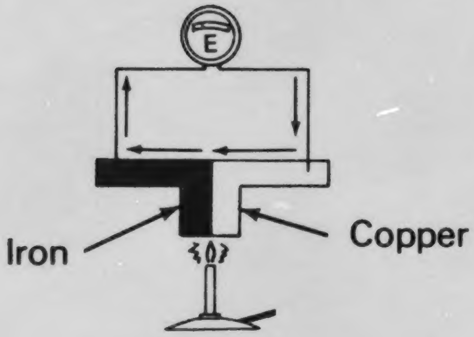
Positive Charge

Negative Charge

Copper Wire

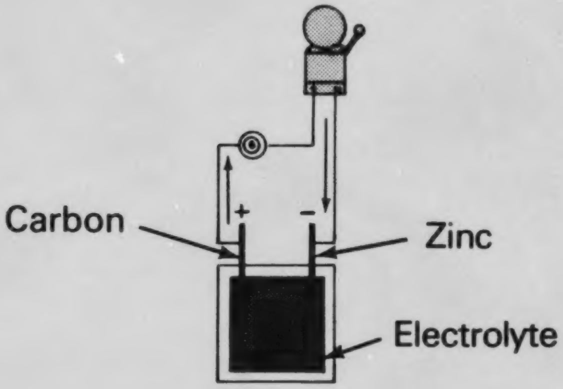
Electron Flow

Sources of Electricity


E
Iron
Copper

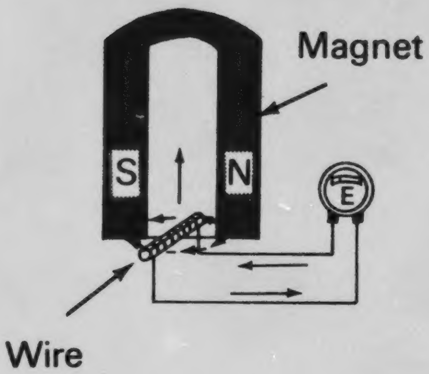
Thermocouple

Thermoelectric Source


Carbon
+
–
Zinc
Electrolyte

Battery

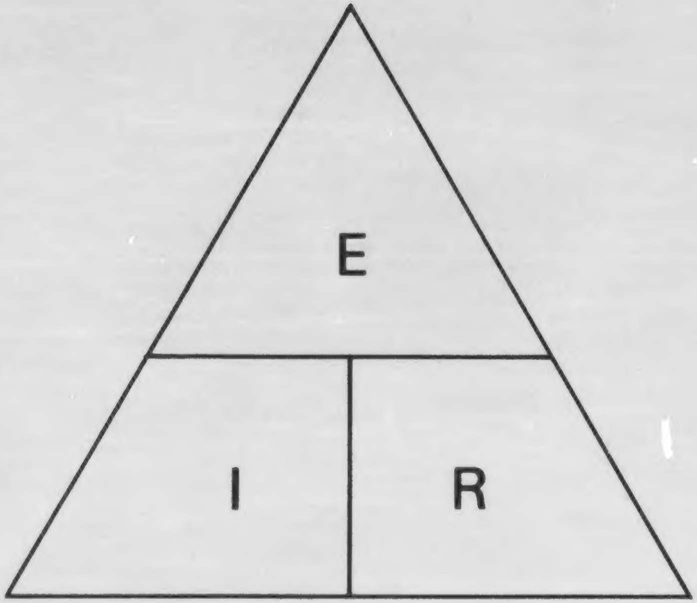
Electrochemical Source


Magnet
S
N
E
Wire

Generator

Electromagnetic Source

Ohm's Law in Triangle Expression



NOTE: Solve for Volts, Amps,
or Resistance by
Covering the Unknown

Example: Cover E, then E = I x R
Cover I, then I = E ÷ R
Cover R, then R = E ÷ I

E = Volts

I = Amps

R = Resistance

Ohm's Law in Letter Designation

Electromotive Force = Current x Resistance

$E = IR$ Volts = Amperes x Ohms

$$\text{Current} = \frac{\text{Electromotive Force}}{\text{Resistance}}$$

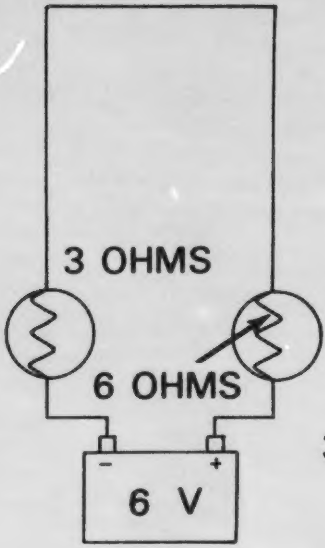
$$I = \frac{E}{R} \qquad \text{Amperes} = \frac{\text{Volts}}{\text{Ohms}}$$

$$\text{Resistance} = \frac{\text{Electromotive Force}}{\text{Current}}$$

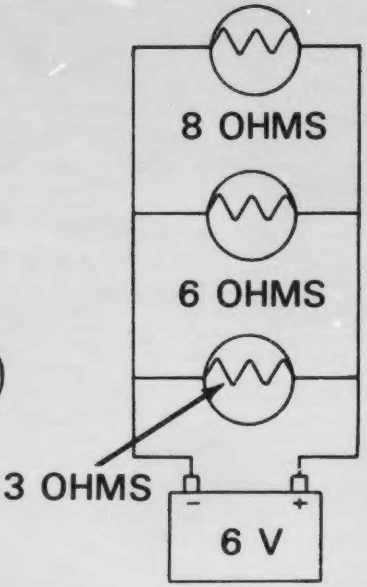
$$R = \frac{E}{I} \qquad \text{Ohms} = \frac{\text{Volts}}{\text{Amperes}}$$

Types Of Electrical Circuits

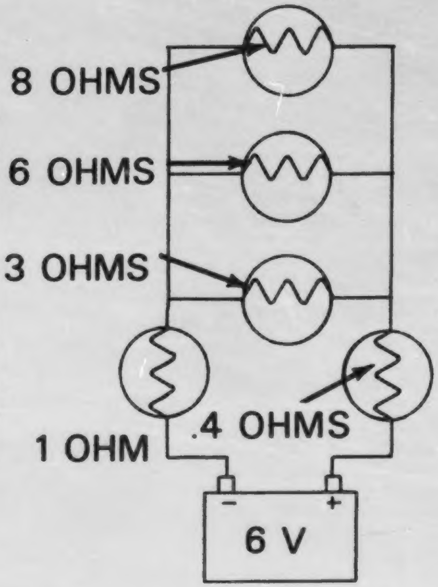
SERIES CIRCUIT


3 OHMS
6 OHMS
6 V
−
+

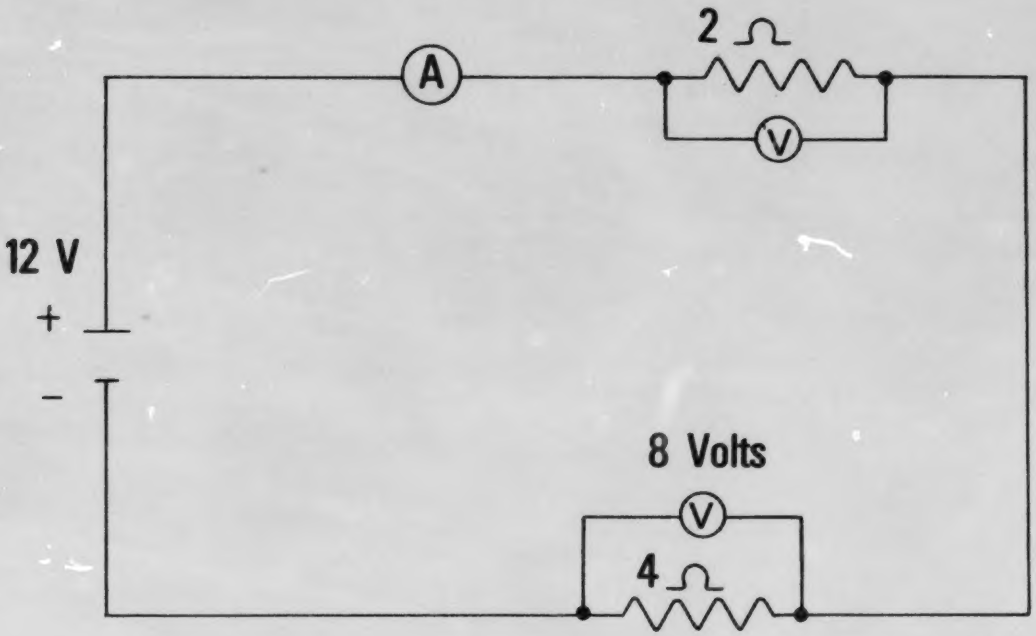
PARALLEL CIRCUIT


8 OHMS
6 OHMS
3 OHMS
6 V
−
+

SERIES-PARALLEL CIRCUIT


8 OHMS
6 OHMS
3 OHMS
1 OHM
.4 OHMS
6 V
−
+

Series Circuit Rules


2 Ω
A
V
12 V
+
–
8 Volts
V
4 Ω

A. I = E/R·I

= 12/6 = 2 Amperes

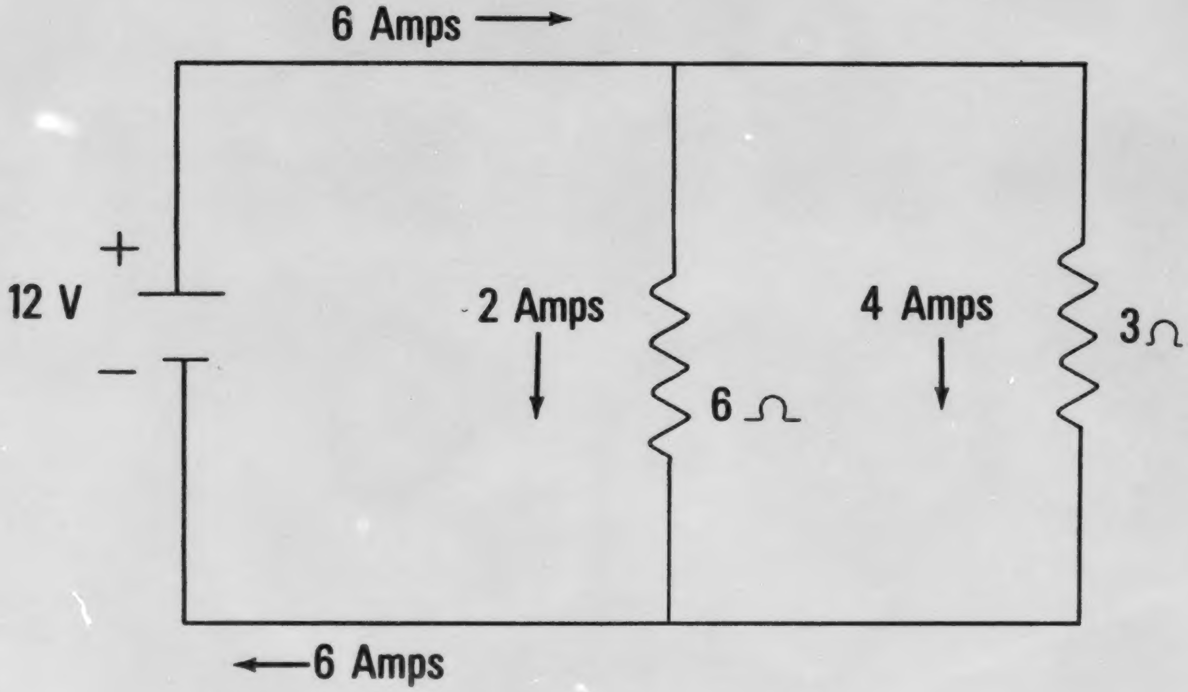
B. E = IR

E = 2×2 = 4 Volts

E = 2×4 = 8 Volts

C. 4+8 =12 Volts

Parallel Circuit Rules

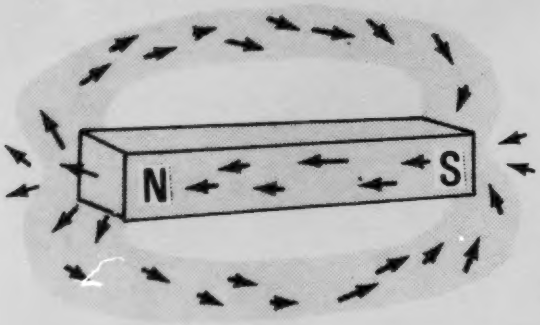

6 Amps
+
12 V
–
2 Amps
6 Ω
4 Amps
3 Ω
6 Amps

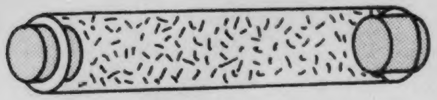
A. Battery voltage across each resistor = 12 Volts

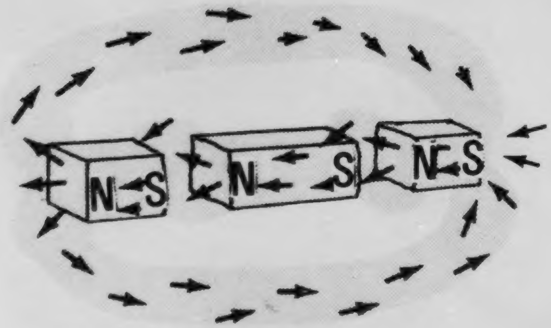
B. I = E/R = 12/6
= 2 Amperes
I = E/R = 12/3
= 4 Amperes

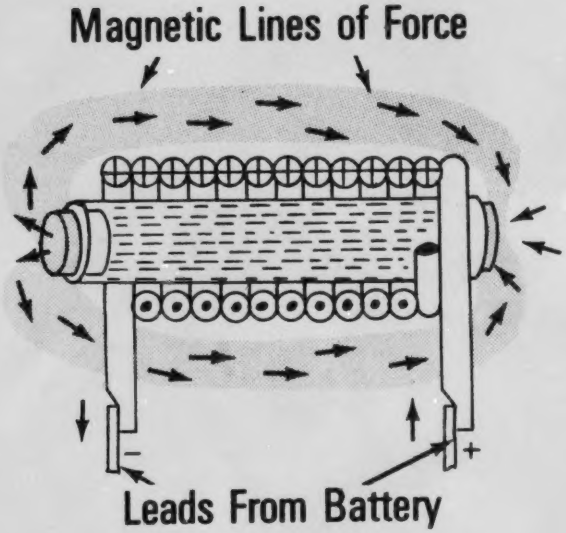
C. I = 6 Amps R = E/I
= 12/6 = 2 Ohms

Magnetism And Field Of Force

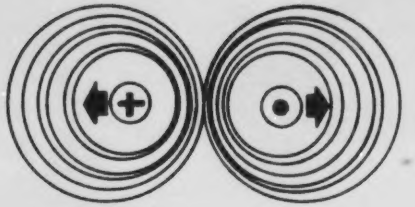



Unmagnetized Iron Filings

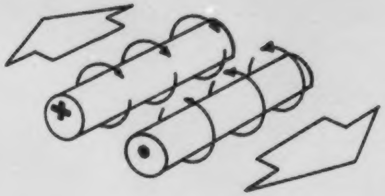



Magnetic Lines of Force
−
+
Leads From Battery

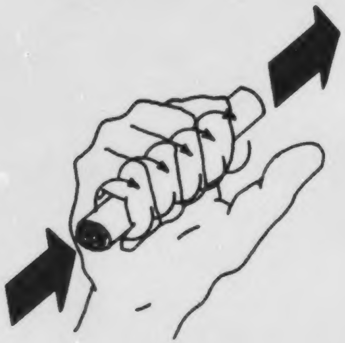
Electricity And Magnetism Relationship



Strong Field Between Conductors

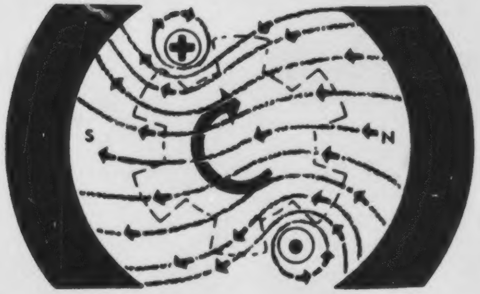


Conductors Tend To Move Apart



Right Hand Rule For Straight Conductor

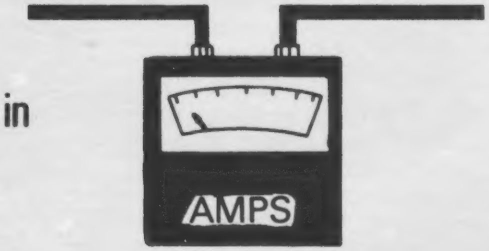
Arrows Show Direction Of Field Of Force

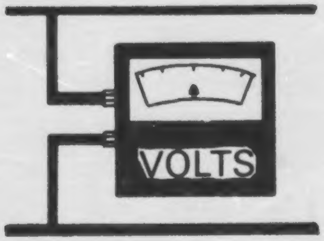


Motor Principle

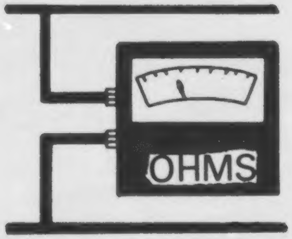
Measuring Instruments

Electric current is measured in amperes with an ammeter.

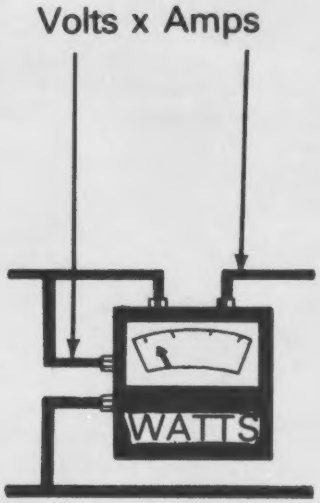




Electric "pressure" is measured in volts with a voltmeter.



Resistance is measured in ohms with a ohmmeter.


Volts x Amps
WATTS

Electric power is measured in watts with a wattmeter.

INTRODUCTION TO ELECTRICAL SYSTEMS
UNIT I

ASSIGNMENT SHEET #1--SOLVE PROBLEMS USING OHM'S LAW

Directions: Read the problems and use the triangle expression of Ohm's Law to solve for the unknown value in each problem.

Example: Cover the unknown in the triangle and solve

(NOTE: E = Voltage; I = Amperes; R = Resistance.)

Show your work on each problem. Turn in to instructor after completion.

1. A current of 4 amperes is needed to operate a certain light bulb having a resistance of 3 ohms. What voltage is required?

2. Through how many ohms resistance does 12 volts force a current of 12 amperes?

ASSIGNMENT SHEET #1

3. An electric horn requires 12 volts; the resistance is 20 ohms. What current does the horn take?

(NOTE: The electrical energy consumed in any resistance appears as heat. There is a definite relation between the power consumed and the heat produced. This is in accordance with the principle that energy cannot be destroyed.)

4. A light bulb having a resistance of 6 ohms, uses 2 amperes of current while in operation. What is the voltage applied to the circuit?

5. A horn connected to a 12 volt battery uses 2 amperes of current for its operation. What is the resistance of the horn?

INTRODUCTION TO ELECTRICAL SYSTEMS
UNIT I

ANSWERS TO ASSIGNMENT SHEET

1. Covering up the E shows the formula for this problem to be I x R. Therefore, E = IR = 4 x 3 = 12 volts.
2. Covering up the R shows that R = E/I which equals 12/12 = 1 ohm.
3. Covering up the I shows that I = E/R. Therefore, 12/20 = .6 amperes.
4. E = I x R. Therefore, 6 x 2 = 12 volts.
5. R = E/I. Therefore, 12/2 = 6 ohms.

INTRODUCTION TO ELECTRICAL SYSTEMS
UNIT I

NAME ______________________________

TEST

1. Match the terms on the right with their correct definitions.

_____ a. Smallest unit of all matter

_____ b. Particles with a negative charge in orbit around a core of protons

_____ c. Particles with a positive charge that make up the nucleus of the atom

_____ d. Flow of electrons through a conductor, measured in amperes

_____ e. Any material that permits passage of electric current

_____ f. An element which has four electrons in outer ring; used to make diodes and transistors; not a good conductor or insulator

_____ g. Potential difference that causes flow of current

_____ h. Opposition to current flow in a conductor

_____ i. Material with an extremely high resistance to current flow

_____ j. Stored chemical energy which can be converted to electrical current

_____ k. Electricity generated by cutting the magnetic lines of force (field) around a magnet

_____ l. Electricity generated by heat

_____ m. Thermoelectric device used to measure temperature accurately

_____ n. Inducing voltage in a conductor that moves across a magnetic field

_____ o. Occurs when changing current in one coil induces voltage in a second coil

1. Resistance
2. Thermoelectric
3. Electrochemical
4. Electromagnetic
5. Electromagnetic induction
6. Electrons
7. Atom
8. Current
9. Generator (direct current)
10. Alternator (alternating current generator)
11. Voltage
12. Protons
13. Watt
14. Power

_____p. Voltage which occurs in a coil when there is a change of current

_____q. Voltage and current produced by moving conductors across a stationary magnetic field

_____r. Voltage and current produced by a rotating magnetic field cutting across stationary conductors

_____s. Force times distance

_____t. Rate of doing work

_____u. Electrical measurement of rate of doing work

_____v. Electromotive force or voltage

_____w. Voltage induced in a conductor which is moving through a magnetic field in opposition to the source of voltage

_____x. One complete reversal of an alternating current from positive to negative and back to the starting point

_____y. Current has more than one path to take

_____z. Current has only one path it can take

_____aa. A circuit consisting of both series and parallel components

_____bb. State of being free from risk

15. Work
16. Thermocouple
17. Emf
18. Cycle (hertz)
19. Series-parallel circuit
20. Conductor
21. Series circuit
22. Insulator
23. Counter emf
24. Parallel circuit
25. Semiconductor
26. Mutual induction
27. Self induction
28. Safety

2. Select true statements concerning safety practices dealing with electrical systems by placing an "X" in the appropriate blanks.

_____a. When working on electrical system that is connected to the battery, remove all jewelry

_____b. When disconnecting battery cables, remove the positive cable first

_____c. If you are using an ohmmeter, disconnect the battery

_____d. Never leave the ignition switch on when installing a distributor

_____e. Never ground the output terminal of the alternator

_____f. Never lay any conductor across the battery terminals

_____g. When replacing an electrical component, always disconnect the battery first

_____ h. Never apply full battery voltage to the fuel tank sending unit

_____ i. When using jumper cables, always connect ground battery negative post

_____ j. When using a battery charger, make your connections before plugging the charger in

_____ k. When adding accessories, make sure they match the vehicle's ground

_____ l. When replacing a conductor, always use the same size (gauge) conductor

_____ m. When adding accessories, be sure to not exceed the charging system output

3. Name two particles found in an atom.

a. ______________________________

b. ______________________________

4. Explain the nature of electron flow.

____

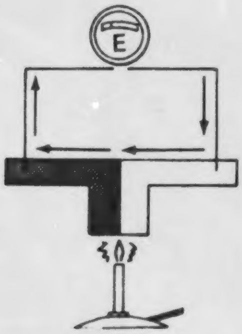
____

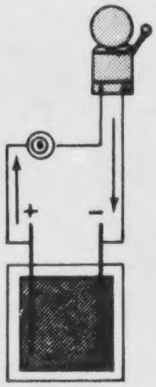
5. Define electricity according to the atomic theory.

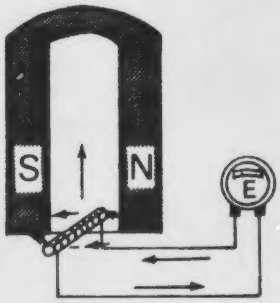
____

____

6. Identify three sources of electricity related to diesel engines.







a. ______________ b. ______________ c. ______________

7. Name three parts of a basic circuit.

   a. ______________________________

   b. ______________________________

   c. ______________________________

8. Distinguish between a good conductor and a good insulator in electron theory by placing an "X" next to the description of an insulator.

   ______a. Has more than four electrons in outer ring

   ______b. Has less than four electrons in outer ring

9. Distinguish between good conductors and insulators of electricity by placing a "C" in front of the items that are good conductors and an "I" in front of the insulators.

   ______a. Mercury

   ______b. Brass

   ______c. Rubber

   ______d. Glass

   ______e. Wood

   ______f. Nickel

   ______g. Plastic

   ______h. Nichrome

   ______i. Silver

   ______j. Gold

   ______k. Ceramic

   ______l. Aluminum

10. Explain why copper is widely used as a conductor.

    ____

11. Match the basic circuit terms on the right with their units of measure.

    ______a. Volts 1. Current

    ______b. Ohms 2. Voltage

    ______c. Amperes 3. Resistance

12. List two causes of resistance to the flow of current (electrons).

a. ______________________________

b. ______________________________

13. Match the basic electrical schematic symbols with their correct names.

_____a. Resistance or load
_____b. Ohm's of resistance
_____c. Inductor (coil)
_____d. Inductor (solenoid)
_____e. Ground
_____f. Battery
_____g. Connection
_____h. Terminal
_____i. Switch (open)
_____j. Circuit breaker
_____k. Crossover
_____l. Direction of current
_____m. Diode (one-way)
_____n. Zener diode
_____o. Transistor (PNP type)
_____p. Transistor (NPN type)
_____q. Capacitor
_____r. Variable resistor
_____s. Fuse

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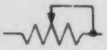
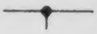
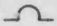
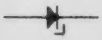
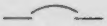
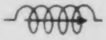
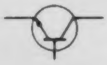
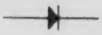
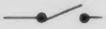
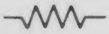
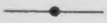
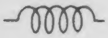
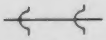
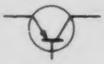
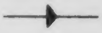
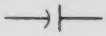
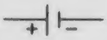
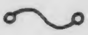
2. 
3. 
4. 
5. 
6. 
7. 
8. 
9. 
10. 
11. 
12. 
13. 
14. 
15. 
16. 
17. 

18. 
19. 

14. Match the letter designations used in Ohm's Law with their correct terms.

_____a. Electromotive force in volts
_____b. Intensity (current) in amps
_____c. Resistance in ohms

1. R
2. I
3. E

15. Draw Ohm's Law formula in triangle expression.

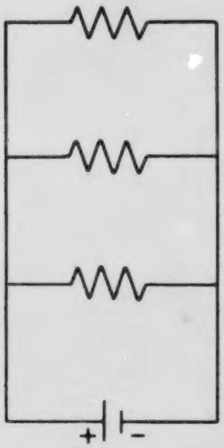
16. State Ohm's Law in letter formula for calculating voltage, current, and resistance.

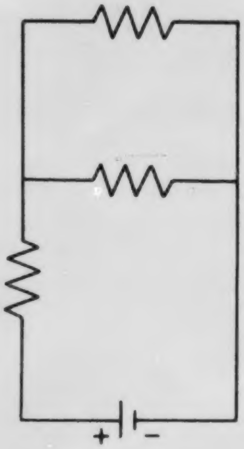
a. ____________________

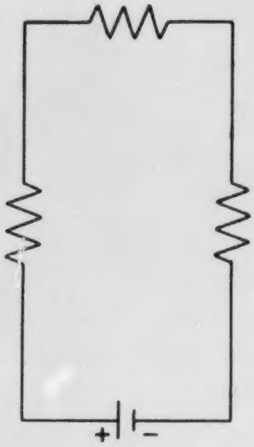
b. ____________________

c. ____________________

17. Identify three types of electrical circuits.







a. __________ b. __________ c. __________

18. List three rules for series circuits

a. ____________________

b. ____________________

c. ____________________

19. List three rules for parallel circuits.

a. ____________________

b. ____________________

c. ____________________

20. Name three factors affecting resistance in a conductor.

a. ______________________________

b. ______________________________

c. ______________________________

21. Select the characteristics of magnetism by placing an "X" in the appropriate blanks.

_____a. Every magnet has a north and south pole

_____b. Like poles attract and unlike poles repel

_____c. Magnetic materials are acted upon when located in a field of force

_____d. Every magnet has a field of force surrounding it

_____e. Unlike poles attract and like poles repel

22. Complete the following list of ways an iron bar may be magnetized.

a. Stroke an iron bar with another bar which has been magnetized

b. ______________________________

____

23. Select true statements concerning the relationship between electricity and magnetism by placing an "X" in the appropriate blanks.

_____a. Current passed through a wire creates a magnetic field around the wire

_____b. Magnetic lines never change direction when the current flow changes direction

_____c. Two conductors on an armature, carrying current in opposite directions, create a strong and weak field on opposite sides causing conductors to move apart or armature to rotate

24. Select true statements concerning the principle of electromagnetic induction by placing an "X" in the appropriate blanks.

_____a. Conductor moving across a magnetic field will have a voltage (emf) induced in it

_____b. Voltage polarity and the current flow direction are determined by the direction of wire movement and direction of the lines of force

25. List three ways in which voltage may be induced by electromagnetic induction.

a. ______________________________

b. ______________________________

c. ______________________________

26. List three factors that determine the magnitude of induced voltage.

a. ______________________________

b. ______________________________

c. ______________________________

27. Name two types of electric current.

a. ______________________________

b. ______________________________

28. Distinguish between direct and alternating current by placing "DC" in front of the items that refer to direct current and "AC" in front of the items that refer to alternating current.

_____a. Flows in one direction then reverses and flows in the opposite direction

_____b. Dry cell battery

_____c. Supplied by an alternating current generator (alternator)

_____d. Flows in one direction only

_____e. Supplied by a generator

29. Name four instruments used in checking electrical circuits.

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

30. Solve problems using Ohm's Law.

a. A current of 1.5 amperes is needed to operate a certain light bulb having a resistance of 8 ohms. What voltage is required?

____

____

b. A horn connected to a 12 volt battery uses 4 amperes of current for its operation. What is the resistance of the horn?

____

____

INTRODUCTION TO ELECTRICAL SYSTEMS
UNIT I

ANSWERS TO TEST

1. a. 7
   b. 6
   c. 12
   d. 8
   e. 20
   f. 25
   g. 11
   h. 1
   i. 22
   j. 3
   k. 4
   l. 2
   m. 16
   n. 5
   o. 26
   p. 27
   q. 9
   r. 10
   s. 15
   t. 14
   u. 13
   v. 17
   w. 23
   x. 18
   y. 24
   z. 21
   aa. 19
   bb. 28

2. a, c, d, e, f, g, h, j, k, l, m

3. a. Electron
   b. Proton

4. When acted upon by a source such as friction, electrons in the outer ring or orbit break away to other atoms

5. The flow of electrons from atom to atom in a conductor

6. a. Thermoelectric
   b. Electrochemical
   c. Electromagnetic

7. a. Voltage
   b. Resistor
   c. Conductor

8. a

9. a. C
   b. C
   c. I
   d. I
   e. I
   f. C
   g. I
   h. C
   i. C
   j. C
   k. I
   l. C

10. Copper has only one electron in outer ring and is comparatively cheaper than other metals which may have the same properties

11. a. 2
    b. 3
    c. 1

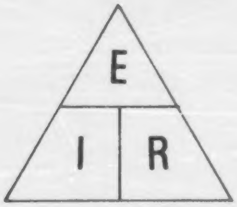
12. a. Core of atoms (protons) attracts orbiting electrons, which resist their removal
    b. Collision of countless electrons as they move

13.

a.	11	f.	18	k.	14	p.	8
b.	4	g.	3	l.	16	q.	17
c.	13	h.	12	m.	9	r.	2
d.	7	i.	10	n.	5	s.	19
e.	1	j.	6	o.	15		

14. a. 3
    b. 2
    c. 1

15.



16. a. $E = I \times R$
    b. $I = E/R$
    c. $R = E/I$

17. a. Parallel
    b. Series-parallel
    c. Series

18. a. Current through each resistor is the same
    b. Voltage drops across each resistor will be different if the resistance values are different
    c. Sum of the voltage drops equals the source voltage

19. a. Voltage across each resistor is the same
    b. Current through each resistor will be different if the resistance values are different
    c. Sum of the separate currents equals the total circuit current

20. a. Length of wire
    b. Diameter of wire
    c. Temperature of wire

21. a, c, d, e

22. b. Place an iron bar in a strong magnetic field

23. a, c

24. a, b

25. a. Generated voltage by relative motion
    b. Self induction voltage created by a change of current in the conductor
    c. Mutual induction voltage which occurs when changing current in one coil induces voltage in a second coil

26. a. Strength of the magnetic field
    b. Speed at which lines of force are cutting across the conductor
    c. Number of conductors that are cutting across the lines of force

27. a. Direct
    b. Alternating

28. a. AC
    b. DC
    c. AC
    d. DC
    e. DC

29. a. Ammeter
    b. Voltmeter
    c. Ohmmeter
    d. Wattmeter

30. a. 12 volts
    b. 3 ohms

ELECTRICAL CIRCUITS
UNIT II

UNIT OBJECTIVE

After completion of this unit, the student should be able to match different types of connectors with their correct names and to identify typical symbols used in a circuit. The student should also be able to demonstrate the ability to check voltage and continuity. This knowledge will be evidenced by correctly performing the procedures outlined in the job sheets and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to electrical circuits with their correct definitions.
2. Match different types of connectors with their correct names.
3. Identify typical symbols used in a circuit.
4. Arrange in order the procedure for checking an electrical circuit from battery to ground.
5. Arrange in order the procedure for troubleshooting an electrical system.
6. Complete a list of types of electrical test equipment.
7. Demonstrate the ability to:
   a. Check voltage.
   b. Check continuity.

ELECTRICAL CIRCUITS
UNIT II

SUGGESTED ACTIVITIES

I. Provide student with objective sheet.

II. Provide student with information and job sheets.

III. Make transparencies.

IV. Discuss unit and specific objectives.

V. Discuss information sheet.

VI. Demonstrate and discuss the procedures outlined in the job sheets.

VII. Have students draw wiring diagrams of a brake light system, horn circuit and/or additional lighting circuit.

VIII. Demonstrate safety practices on electrical systems.

IX. Show film on safety procedures to follow when working on electrical systems.

X. Take a field trip to a shop where electrical work is performed.

XI. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

  A. Objective sheet

  B. Information sheet

  C. Transparency masters

    1. TM 1--Typical Symbols in an Electrical Circuit

    2. TM 2--Typical Symbols in an Electrical Circuit (Continued)

    3. TM 3--Typical Symbols in an Electrical Circuit (Continued)

    4. TM 4--Typical Headlight Circuit

  D. Job sheets

    1. Job Sheet #1--Check Voltage

    2. Job Sheet #2--Check Continuity

E. Test

F. Answers to test

II. References

A. Schulz, Erich J. *Diesel Mechanics.* New York: Gregg Division, McGraw-Hill Book Company, 1977.

B. *Fundamentals of Service: Electrical Systems.* Fourth Edition. Moline, IL: Deere and Company, 1979.

C. Dagel, John F. *Diesel Engine Repair.* New York: John Wiley and Sons, Inc., 1982.

ELECTRICAL CIRCUITS
UNIT II

INFORMATION SHEET

I. Terms and definitions

(NOTE: Refer to Unit I for symbols.)

A. Switch--A device that opens and closes a circuit

B. Fuse--A metal strip which melts, or blows out, if excessive current flows through it; rated in amps, it protects electrical devices from excessive current

C. Connector--A device that is connected to a cable to allow the cable to be connected to a post or bolt

D. Cable--Stranded conductors, usually covered with insulating material

E. AC--Alternating current

F. Alternator (alternating current generator)--Voltage and current produced by a rotating magnetic field cutting across stationary conductors

G. Generator (direct current)--Voltage and current produced by moving conductors across a stationary magnetic field

H. Ampere--A unit of electrical current

I. Amperage--The amount of current flowing, in amperes

J. Ammeter--A meter that measures the amount of current flowing in a circuit

K. Open circuit--A circuit in which a wire is broken or disconnected

L. Short circuit--Wire touching another wire and providing a shorter path for current to flow

M. Grounded circuit--A circuit in which a wire touches ground causing the current to flow to ground instead of through the circuit

N. Circuit breaker--A device that opens an electrical circuit when limiting conditions are reached

(NOTE: Cutout relays are sometimes called circuit breakers.)

O. Condenser--An electrical energy absorbing device

(NOTE: Capacitors are also called condensers.)

P. Conductor--Any device that provides a path for current flow

Q. Current--A flow of electrons, measured in amperes

INFORMATION SHEET

R. Current-limit relay--A relay that opens its contacts when the limiting current flows in a circuit

S. Current regulator--A regulating device that limits the charging rate

T. DC--Direct current

U. Diode--A P-N junction or an N-P junction that limits electrical flow to one direction only

(NOTE: A diode rectifies current.)

V. Zener diode--A diode that limits reversed bias up to a predetermined value

W. Transistor--A semiconductor that can be used as an amplifier or a trigger

(NOTE: A transistor consists of two diodes back to back that share a common base.)

X. Lead--A cable capable of carrying current

Y. Integrated circuit (IC)--Sealed unit containing resistors, diodes, and transistors

(NOTE: IC's are not repairable; they must be replaced.)

Z. Wiring diagram (schematic)--A drawing that uses electrical symbols and lines to show electrical circuits

AA. Jumper wire--A wire usually with alligator clips that is used to provide current or ground to an electrical device

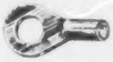
BB. Test light--A test instrument used to find current flow

CC. Continuity light--A self powered test light, used to check for open circuits

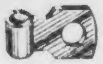
(CAUTION: Do not hook into live circuit.)

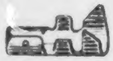
DD. Junction block--A multiple connection point for current or ground which can also be used as a test point

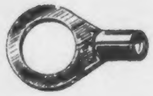
II. Types of connectors

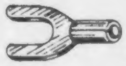
A. Ring type (eyelet) 

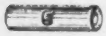
INFORMATION SHEET

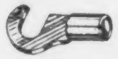
B. Roll type 

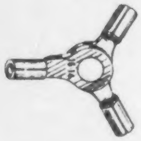
C. Female snap on 

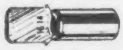
D. Lug type 

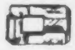
E. Slotted-flange bay type 

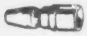
F. Insulated butt connector 

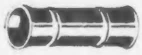
G. Slotted hook type 

H. Three way connector 

I. Male slide connector 

J. Female slide connector 

K. Male plug connector (bullet connector) 

L. Female plug connector (bullet connector) 

III. Typical symbols in a circuit (Transparencies 1, 2, and 3)

A. One pole, two position switch

B. Switches that move together

C. Two contacts in the same connector

INFORMATION SHEET

D. Brake warning indicator

E. Connector attached to component

F. Relay shown with no current flowing through coil

G. Screw terminal connected to fusible link

H. Dashed wire reference

I. Wire choices for options or different models

J. Fuse with black plug in connector

K. Diode

L. Two pole, six position switch

M. Junction block connection

N. Entire component

O. Part of a component

P. Details of component

Q. Component grounded to frame

R. Ground reference

S. Solid state

T. Connector reference

U. Five cavity connector

V. Five cavity connector (four used)

W. Parts of the same connector

X. Connector on component lead

(NOTE: Lead is pronounced Leed.)

Y. Wire size labeled in square mm

(NOTE: This also appears in AWG gauge.)

Z. Break in wire symbol

AA. Color stripe designation

BB. Wire size labeled in color

INFORMATION SHEET

CC. Cut wire reference

DD. Circuit reference

IV. Checking an electrical circuit from battery to ground (Transparency 4)

A. Locate junction block or fuse panel or breaker panel

B. Identify color coding on wire from power source

C. Trace wire to component

D. Isolate problem

E. Repair as necessary

V. Troubleshooting an electrical system

A. Operate circuit to verify the complaint

B. Read the electrical diagram

C. Find the cause and repair it

D. Check the repair

VI. Types of electrical test equipment

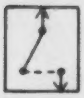
A. Test light

B. Voltmeter

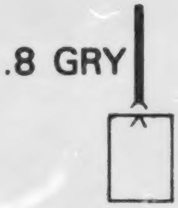
C. Ammeter

D. Ohmmeter

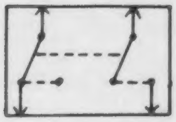
Typical Symbols In An Electrical Circuit



One Pole,
Two Position
Switch

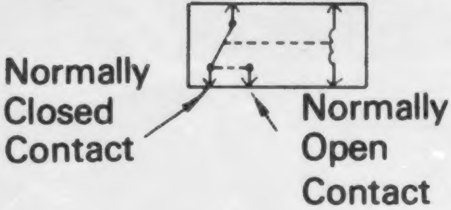


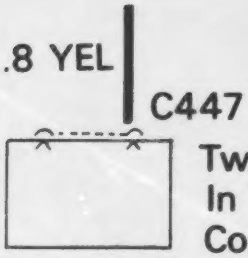
Connector
Attached To
Component



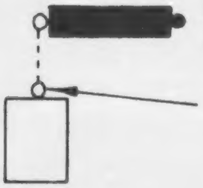
Switches That
Move Together

Relay Shown
With No
Current Flowing
Through Coil

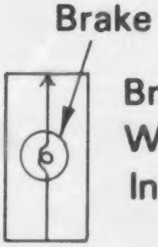

Normally
Closed
Contact
Normally
Open
Contact



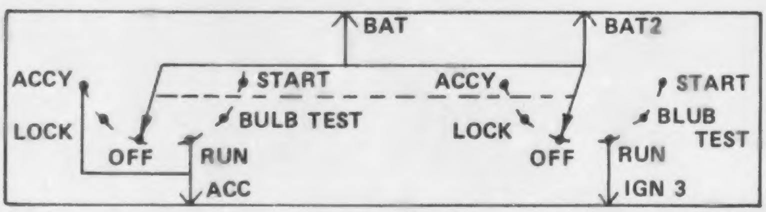
Two Contacts
In The Same
Connector



Screw
Terminal
Connected
To Fusible
Link



Brake
Warning
Indicator

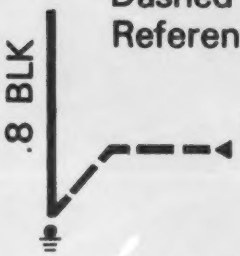

BAT
BAT2
ACCY
START
ACCY
START
LOCK
BULB TEST
LOCK
BLUB
TEST
OFF
RUN
OFF
RUN
ACC
IGN 3

Two Pole,
Six Position
Switch

Typical Symbols In An Electrical Circuit

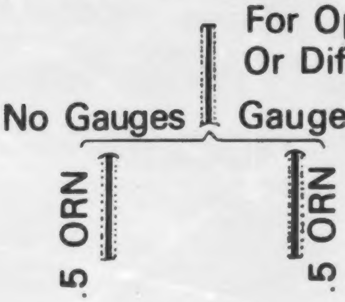
(Continued)

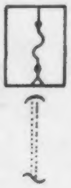
Dashed Wire Reference



See Ground Distribution

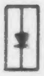
Wire Choices For Options Or Different Models


No Gauges
Gauges
.5 ORN
.5 ORN



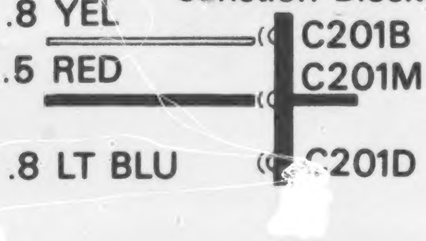
Fuse With Black Plug In Connector

Diode



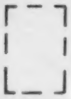
(Current Can Flow Only In The Direction Of The Arrow)

Junction Block Conection

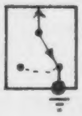

.8 YEL
.5 RED
.8 LT BLU
C201B
C201M
C201D

Entire Component

Part Of A Component



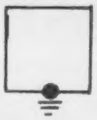
Park Brake Switch



Details Of Component

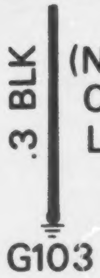
Closed With Parking Brake On

Component



Grounded To Frame

Ground Reference



(Number For Component Location Chart)

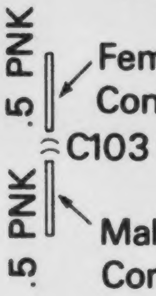
Solid State

Solid State

(Includes Only Electronic Parts)

Typical Symbols In An Electrical Circuit

(Continued)

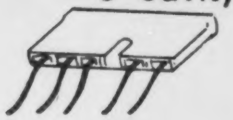

.5 PNK
C103
.5 PNK

Connector Reference (Number For Component Location Chart)

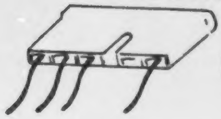
Female Contact

Male Contact

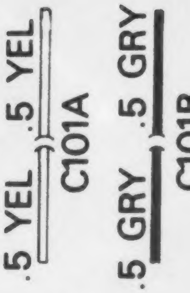
5 Cavity Connector



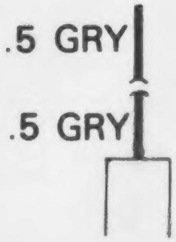
5 Cavity Connector



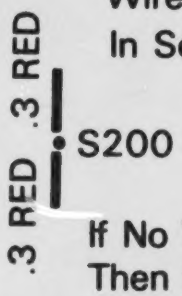
(4 Used)


.5 YEL
C101A
.5 YEL
.5 GRY
C101B
.5 GRY

Parts Of The Same Connector

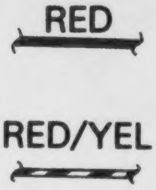


Connector On Component Lead (Pigtail)


.3 RED
S200
.3 RED

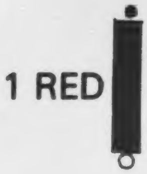
Wire Size Is Labeled In Square (Millimeters)

If No Wire Size Is Labeled, Then Replace Wire With Matching Size



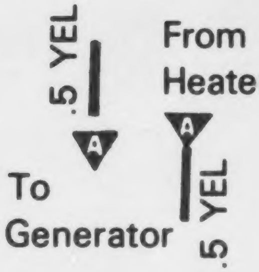
Break In Wire Symbol (Shown By Wavy Line)

Color Strip Designation



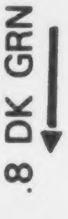
Fusible Link

Wire Size Labeled In Color


.5 YEL
A
To Generator
A
.5 YEL

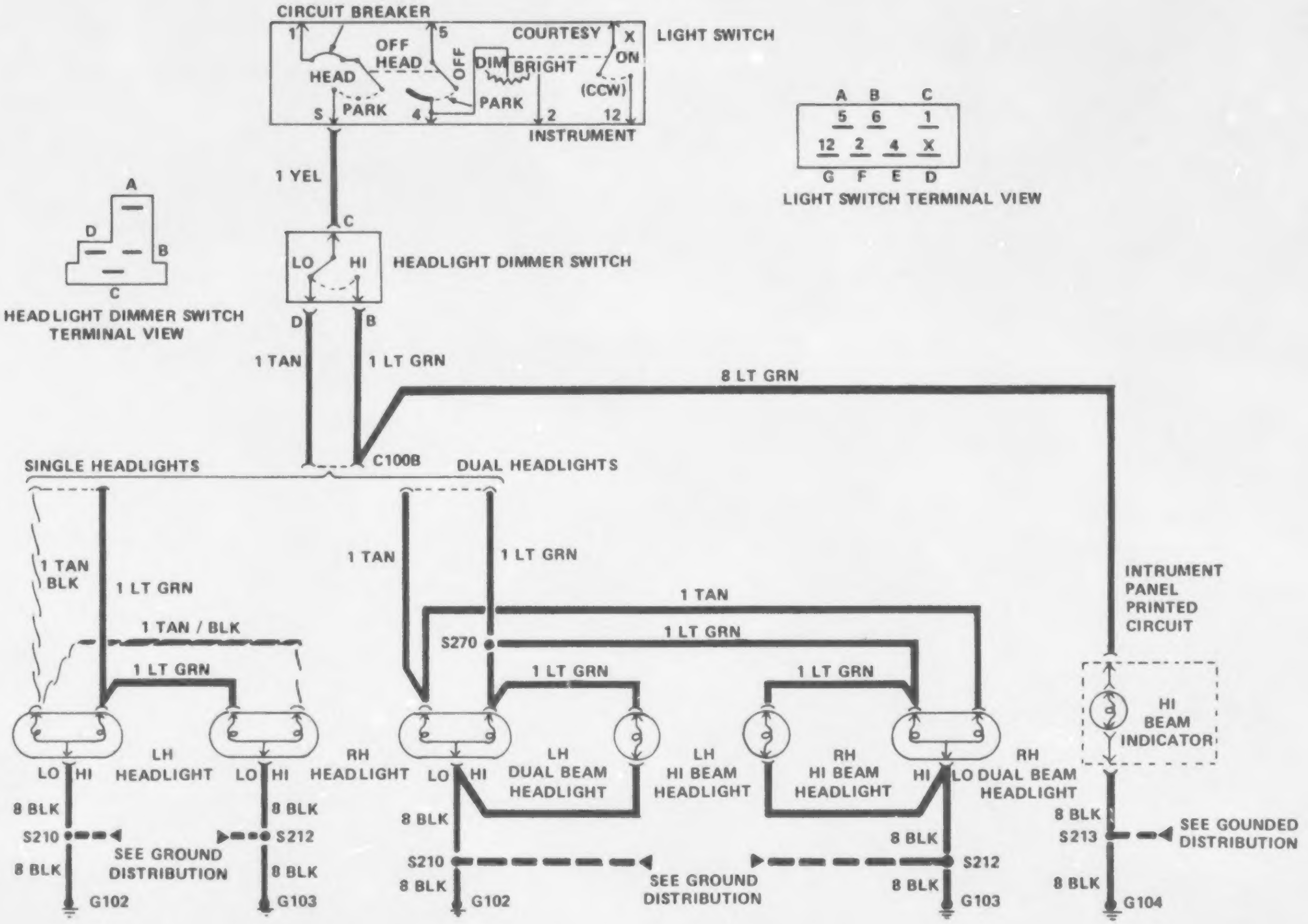
From Choke Heater Relay

Cut Wire Reference



Circuit Reference

Typical Headlight Circuit


CIRCUIT BREAKER
1
5
OFF
HEAD
OFF HEAD
OFF
DIM
BRIGHT
COURTESY
X
ON
(CCW)
PARK
PARK
S
4
2
12
INSTRUMENT
LIGHT SWITCH
A B C
5 6 1
12 2 4 X
G F E D
LIGHT SWITCH TERMINAL VIEW
1 YEL
C
LO
HI
HEADLIGHT DIMMER SWITCH
D
B
A
D
B
C
HEADLIGHT DIMMER SWITCH TERMINAL VIEW
1 TAN
1 LT GRN
8 LT GRN
C100B
SINGLE HEADLIGHTS
DUAL HEADLIGHTS
1 TAN BLK
1 LT GRN
1 TAN / BLK
1 LT GRN
1 TAN
1 LT GRN
1 TAN
S270
1 LT GRN
1 LT GRN
1 LT GRN
INTRUMENT PANEL PRINTED CIRCUIT
HI BEAM INDICATOR
LO
HI
LH HEADLIGHT
LO
HI
RH HEADLIGHT
LO
HI
LH DUAL BEAM HEADLIGHT
LH HI BEAM HEADLIGHT
RH HI BEAM HEADLIGHT
HI
LO
RH DUAL BEAM HEADLIGHT
8 BLK
S210
SEE GROUND DISTRIBUTION
8 BLK
G102
8 BLK
S212
8 BLK
G103
8 BLK
S210
8 BLK
G102
SEE GROUND DISTRIBUTION
8 BLK
S212
8 BLK
G103
8 BLK
S213
SEE GOUNDED DISTRIBUTION
8 BLK
G104

ELECTRICAL CIRCUITS
UNIT II

JOB SHEET #1--CHECK VOLTAGE

I. Tools and materials

- A. Battery
- B. Voltmeter
- C. Appropriate service manual

II. Procedure

(CAUTION: Remove all jewelry before working on any electrical circuit and follow all shop safety procedures.)

- A. Connect negative lead from voltmeter to negative (-) battery terminal
- B. Connect positive lead to positive terminal (+)
- C. Read voltmeter scale and see if you have battery rated voltage
- D. Charge battery to its rating before performing any other electrical tests if you don't have normal battery voltage

ELECTRICAL CIRCUITS
UNIT II

JOB SHEET #2--CHECK CONTINUITY

I. Tools and materials

   A. Battery

   B. Ohmmeter

   C. Appropriate service manual

II. Procedure

   (CAUTION: Remove all jewelry before working on any electrical circuit and follow all shop safety procedures.)

   A. Disconnect battery ground cable

      (CAUTION: Continuity light will be destroyed if this is not done.)

   B. Connect positive lead of the ohmmeter to hot lead of the circuit

   C. Connect negative lead to ground

   D. If the bulb lights, or if the ohmmeter shows minor resistance, the circuit is okay

      (NOTE: Switches and grounds are checked in the same manner.)

ELECTRICAL CIRCUITS
UNIT II

NAME ____________________________

TEST

1. Match the terms on the right with their correct definitions.

_____a. A device that opens and closes a circuit

_____b. A metal strip which melts, or blows out, if excessive current flows through it; rated in amps, it protects electrical devices from excessive current

_____c. A device that is connected to a cable to allow the cable to be connected to a post or bolt

_____d. Stranded conductors, usually covered with insulating material

_____e. Alternating current

_____f. Voltage and current produced by a rotating magnetic field cutting across stationary conductors

_____g. Voltage and current produced by moving conductors across a stationary magnetic field

_____h. A unit of electrical current

_____i. The amount of current flowing, in amperes

_____j. A meter that measures the amount of current flowing in a circuit

_____k. Circuit in which a wire is broken or disconnected

_____l. Wire touching another wire and providing a shorter path for current to flow

_____m. Circuit in which a wire touches ground causing the current to flow to ground instead of through the circuit

_____n. A device that opens an electrical circuit when limiting conditions are reached

_____o. An electrical energy absorbing device

_____p. Any device that provides a path for current flow

1. Conductor
2. Circuit breaker
3. Amperage
4. AC
5. Connector
6. Fuse
7. Transistor
8. Zener diode
9. DC
10. Diode
11. Current regulator
12. Current-limit relay
13. Wiring diagram
14. Test light
15. Jumper wire
16. Grounded circuit

______q. A flow of electrons, measured in amperes

______r. A relay that opens its contacts when the limiting current flows in a circuit

______s. A regulating device that limits the charging rate

______t. Direct current

______u. A P-N junction or an N-P junction that limits electrical flow to one direction only

______v. A diode that limits reversed bias up to a predetermined valve

______w. A semiconductor that can be used as an amplifier or a trigger

______x. A cable capable of carrying current

______y. Sealed unit containing resistors, diodes, and transistors

______z. A drawing that uses electrical symbols and lines to show electrical circuits

______aa. A wire usually with alligator clips that is used to provide current or ground to an electrical device

______bb. A test instrument used to find current flow

______cc. A self powered test light, used to check for open circuits

______dd. A multiple connection point for current or ground which can also be used as a test point

17. Continuity light
18. Junction block
19. Current
20. Lead
21. Short circuit
22. Integrated circuit
23. Switch
24. Cable
25. Generator
26. Ammeter
27. Condenser
28. Ampere
29. Alternator
30. Open circuit

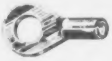
2. Match the different types of connectors on the right with their correct names.

______a. Three way connector

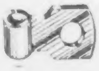
______b. Roll type

______c. Female slide connector

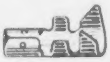
1.



2.



3.



_____d. Female snap-on

_____e. Insulated butt connector

_____f. Slotted-flange bay type

_____g. Lug type

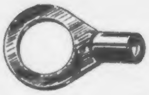
_____h. Ring type

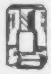
_____i. Male slide connector

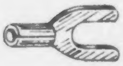
_____j. Male plug connector

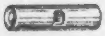
_____k. Slotted hook type

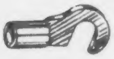
_____l. Female plug connector

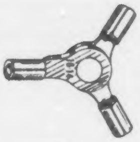
4.


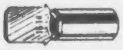
5.


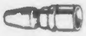
6.


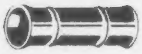
7.


8.


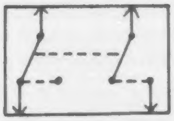
9.


10.


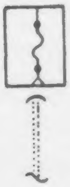
11.


12.


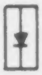
3. Identify symbols used in a circuit.



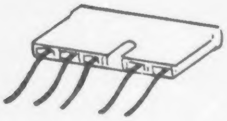
a. ______________________________



b. ______________________________



c. ______________________________



d. ______________________________

4. Arrange in order the procedure for checking an electrical circuit from battery to ground by placing the correct sequence number in the appropriate blank.

_____a. Locate junction block or fuse panel or breaker panel

_____b. Repair as necessary

_____c. Trace wire to component

_____d. Isolate problem

_____e. Identify color coding on wire from power source

5. Arrange in order the procedure for troubleshooting an electrical system by placing the correct sequence number in the appropriate blank.

_____a. Find the cause and repair it

_____b. Check the repair

_____c. Read the electrical diagram

_____d. Operate circuit to verify the complaint

6. Complete the following list of types of electrical test equipment.

a. Test light

b. Ammeter

c. ______________________________

d. ______________________________

7. Demonstrate the ability to:

a. Check voltage.

b. Check continuity.

(NOTE: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

ELECTRICAL CIRCUITS
UNIT II

ANSWERS TO TEST

1. a. 23
   b. 6
   c. 5
   d. 24
   e. 4
   f. 29
   g. 25
   h. 28
   i. 3
   j. 26
   k. 30
   l. 21
   m. 16
   n. 2
   o. 27
   p. 1
   q. 19
   r. 12
   s. 11
   t. 9
   u. 10
   v. 8
   w. 7
   x. 20
   y. 22
   z. 13
   aa. 15
   bb. 14
   cc. 17
   dd. 18

2. a. 9
   b. 2
   c. 5
   d. 3
   e. 7
   f. 6
   g. 4
   h. 1
   i. 10
   j. 11
   k. 8
   l. 12

3. a. Switches that move together
   b. Fuse with black plug in connector
   c. Diode
   d. Five cavity connector

4. a. 1
   b. 5
   c. 3
   d. 4
   e. 2

5. a. 3
   b. 4
   c. 2
   d. 1

6. c. Ohmmeter
   d. Voltmeter

7. Performance skills evaluated to the satisfaction of the instructor

ELECTRICAL INDICATOR CIRCUITS
UNIT III

UNIT OBJECTIVE

After completion of this unit, the student should be able to identify the types of gauges used in testing electrical indicator circuits. The student should also be able to demonstrate the ability to test a fuel level gauge sending unit and check for a grounded circuit. This knowledge will be evidenced by correctly performing the procedures outlined in the job sheets and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to electrical indicator circuits with their correct definitions.
2. Identify types of gauges.
3. Complete a list of parts in a gauge circuit.
4. Select true statements concerning the testing procedures for an ammeter gauge.
5. Complete a list of procedures for testing a fuel level gauge that fails to register.
6. Select true statements concerning the procedures for testing a temperature gauge.
7. Complete a list of procedures for testing a voltmeter.
8. Demonstrate the ability to:
    a. Test the fuel level gauge sending unit.
    b. Check for a grounded circuit.

ELECTRICAL INDICATOR CIRCUITS
UNIT III

SUGGESTED ACTIVITIES

I. Provide student with objective sheet.

II. Provide student with information and job sheets.

III. Make transparencies.

IV. Discuss unit and specific objectives.

V. Discuss information sheet.

VI. Demonstrate and discuss the procedures outlined in the job sheets.

VII. Have students draw some electrical circuits.

VIII. Have students visit different industries and make a list of various types of gauges used.

IX. Invite a guest speaker from a shop that specializes in automotive electrical repair.

X. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

  A. Objective sheet

  B. Information sheet

  C. Transparency masters

    1. TM 1--Instrument Voltage Regulator

    2. TM 2--Types of Gauges

    3. TM 3--Typical Gauge Circuit

    4. TM 4--Electrical Oil Pressure Indicating Systems

  D. Job sheets

    1. Job Sheet #1--Test the Fuel Level Gauge Sending Unit

    2. Job Sheet #2--Check for a Grounded Circuit

E. Test

F. Answers to test

II. References:

A. Stinson, Karl. *Diesel Engineering Handbook*. Stamford, CT 06904: Business Journals, Inc., 1972.

B. *Fundamentals of Service: Electrical Systems*. Fourth Edition. Moline, IL: Deere and Company, 1979.

C. Dagel, John F. *Diesel Engine Repair*. New York: John Wiley and Sons, Inc., 1982.

ELECTRICAL INDICATOR CIRCUITS
UNIT III

INFORMATION SHEET

I. Terms and definitions

  A. Conductor--Path through which current flows

  B. Gauge--An instrument with a graduated scale

  (NOTE: An alternate spelling for gauge is *gage*. The spelling *gage* is used more commonly in service manuals.)

  C. Open--A place, or places, in a conductor that are disconnected or broken

  D. Short--Where a current carrying conductor contacts another current carrying conductor

  E. Ground--Where a current carrying conductor touches the frame

  F. Ammeter gauge--Measures current flow

  G. Ohmmeter--Measures resistance to current flow

  (CAUTION: Do not check a live current with an ohmmeter.)

  H. Voltmeter--Gauge that measures voltage or pressure

  I. Indicator light--A light in the dash that indicates a problem in the system

  J. Current--The amount of amperage flowing in a circuit

  K. Voltage--The amount of potential pressure

  L. Ohm--The amount of resistance in a circuit

  M. Balancing coil--Two or more coils of wire that pull the indicator needle

  N. Instrument voltage regulator--Regulates voltage from the battery and charging system to a constant volt output to the indicating devices (Transparency 1)

  O. Thermocouple--A wire consisting of two different types of metals welded together that when heated produce a small current flow

  P. Pyrometer--A sensitive voltmeter that measures exhaust temperature

II. Types of gauges (Transparency 2)

  A. Loop type

  B. Moving vane type

  C. Balancing coil

INFORMATION SHEET

III. Parts in a gauge circuit (Transparency 3)

- A. Ammeter gauge
- B. Fuel level gauge
- C. Temperature gauge
- D. Oil pressure gauge (Transparency 4)
- E. Voltmeter
- F. Pyrometer

  (NOTE: The pyrometer is used on most turbocharged engines.)

- G. Sending units
- H. Resistance units
- I. Wiring that connects the units
- J. Instrument voltage regulator

  (NOTE: The instrument voltage regulator is not used on all applications.)

- K. Warning light

IV. Testing procedures for an ammeter gauge

- A. If the ammeter gauge fails to register, use the following testing procedures:
  1. Turn all accessories off and start the engine; the ammeter should indicate a charge

     (NOTE: If it does not charge, either the ammeter or the charging system is at fault.)

  2. To check the ammeter, stop the engine and turn on the headlights; the ammeter should show a discharge; if it does not show a discharge, replace the ammeter

- B. If the ammeter reads in reverse--The wires are crossed on the back connections; disconnect them, reverse them, and reconnect them

  (CAUTION: Do not overtighten the connection as this will distort the ammeter mechanism.)

V. Procedures for testing a fuel level gauge that fails to register

- A. Check all wire connections and wires for opens

INFORMATION SHEET

B. Use a sending unit that you know is good or short out the original sending unit

(CAUTION: When performing this test, turn the ignition switch off when the pointer reaches half way on the gauge. This will prevent damage to the gauge.)

C. Use an ohmmeter with the following procedures:

1. Remove the sending unit from the tank

2. Connect an ohmmeter to the threaded connection and housing; with the float in the empty position you should not have a reading

   (NOTE: On some vehicles, it is reverse to this.)

3. Now move the float arm to the full position and note the reading

   (NOTE: You will not have a reading on some vehicles when full position is up. Refer to the manufacturer's specifications to find sending unit values.)

VI. Procedures for testing a temperature gauge

A. If temperature gauge fails to register, use the following testing procedures:

1. Check all wire connections and wires for opens or shorts

2. Ground the unit and the pointer should start to move; if not, replace the unit

3. If pointer moves, sending unit is at fault

B. If the temperature gauge registers hot at all times--Grounded wire or unit is at fault

VII. Procedures for testing a voltmeter

A. If the voltmeter fails to register voltage--Indicates an open in either the wiring or the gauge

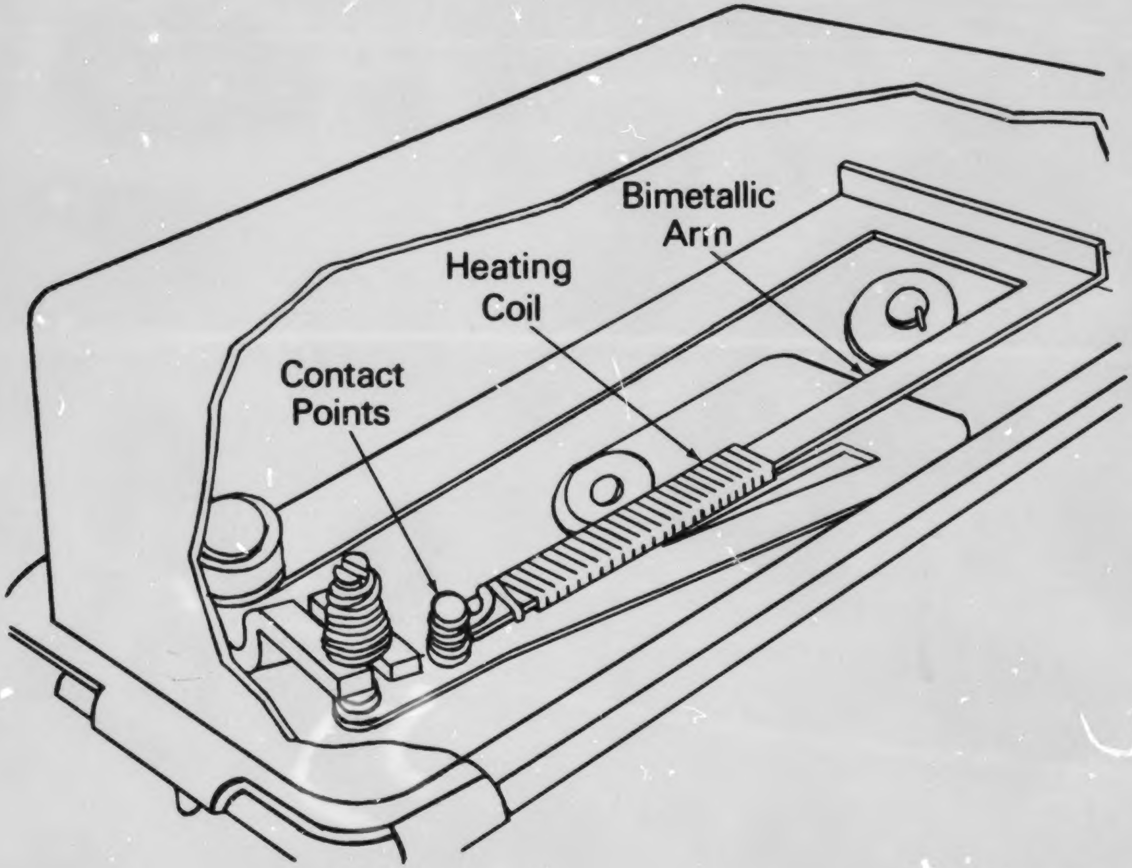
B. If the voltmeter registers in reverse or shows lower than normal system voltage, use the following testing procedures:

1. Check for grounded system

   (NOTE: To check for grounds, place a test light in series with the negative side of the battery; if the light lights with the ignition switch and all accessories are off, you have a ground.)

2. Check battery connections for reversed polarity

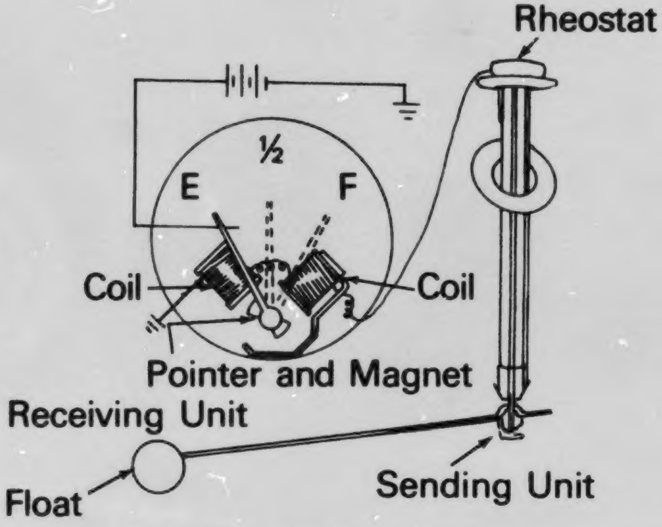
Instrument Voltage Regulator


Bimetallic Arm
Heating Coil
Contact Points

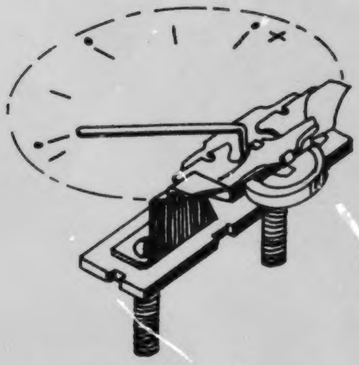
97

98

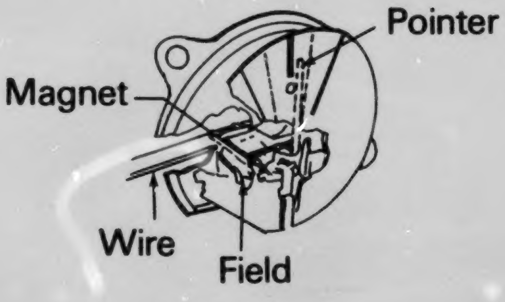
Types of Gauges


Rheostat
E
½
F
Coil
Coil
Pointer and Magnet
Receiving Unit
Float
Sending Unit

Balancing Coil Gauge

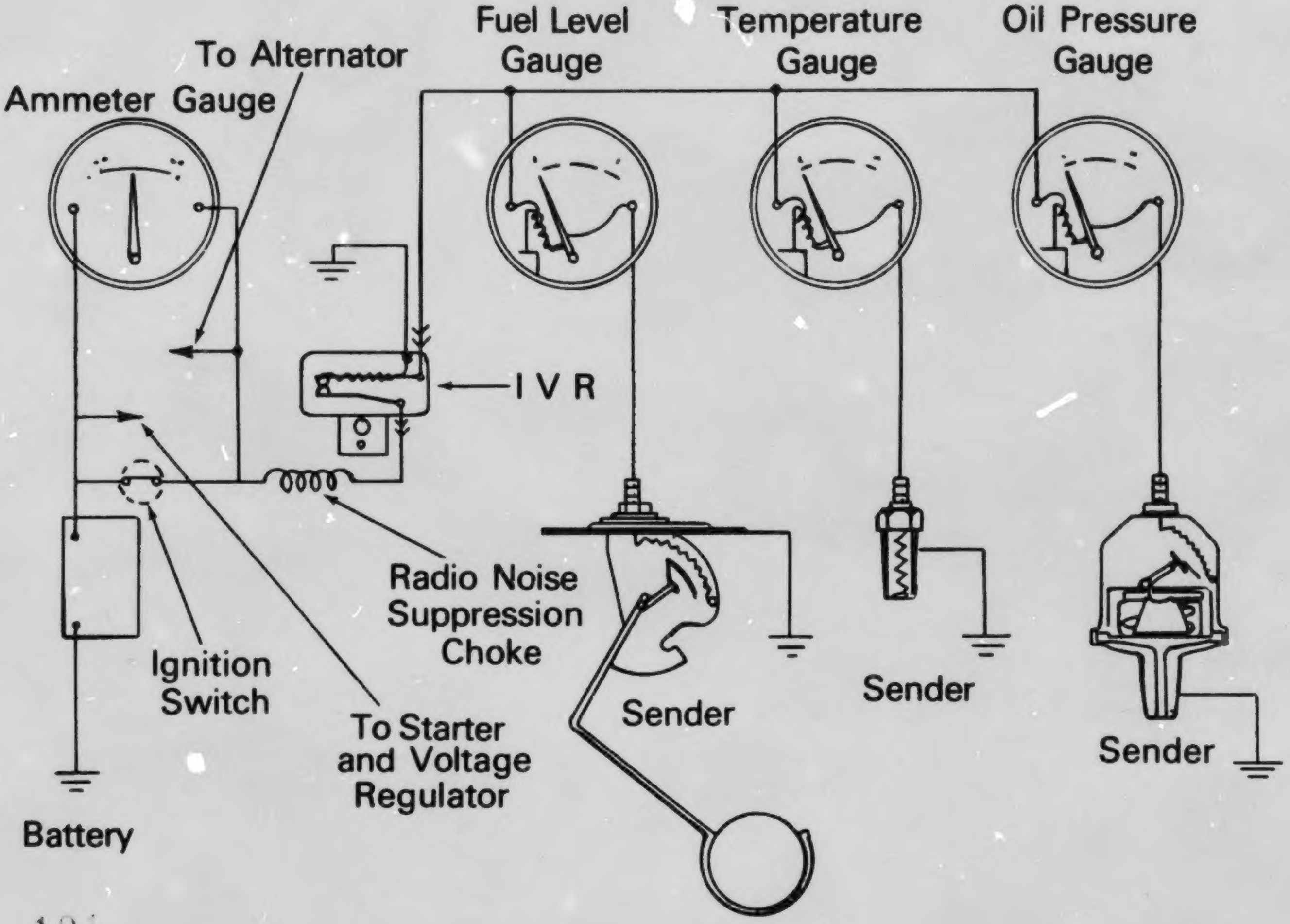


Moving Vane Type


Pointer
Magnet
Wire
Field

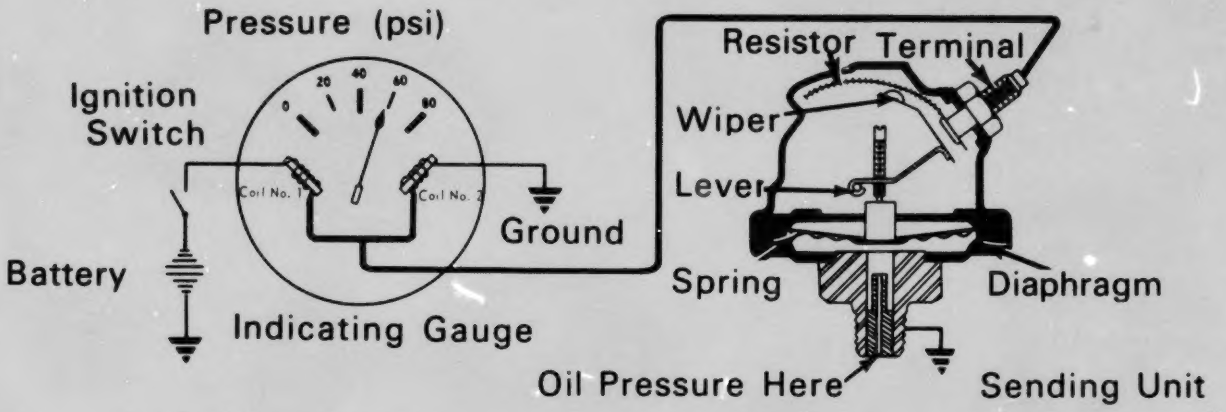
Loop Type

Typical Gauge Circuit

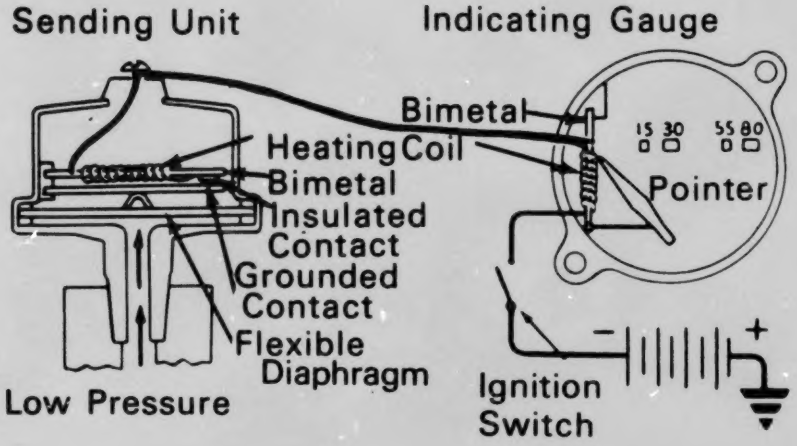


Fuel Level Gauge
Temperature Gauge
Oil Pressure Gauge
To Alternator
Ammeter Gauge
I V R
Radio Noise Suppression Choke
Sender
Sender
Sender
Ignition Switch
To Starter and Voltage Regulator
Battery

Electrical Oil Pressure Indicating Systems


Pressure (psi)
0
20
40
60
80
Ignition Switch
Coil No. 1
Coil No. 2
Ground
Battery
Indicating Gauge
Resistor
Terminal
Wiper
Lever
Spring
Diaphragm
Oil Pressure Here
Sending Unit

Electromagnetic Coil System for Indicating Oil Pressure

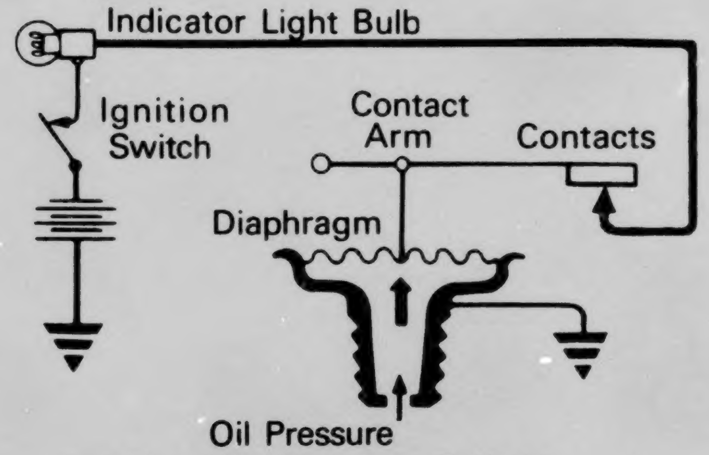

Sending Unit
Indicating Gauge
Bimetal
Heating Coil
Bimetal
Insulated Contact
Grounded Contact
Flexible Diaphragm
Low Pressure
15 30
55 80
Pointer
Ignition Switch
−
+

Operation with Low Oil Pressure

Heating Coil System for Indicating Oil Pressure

TM 4

103


Indicator Light Bulb
Ignition Switch
Contact Arm
Contacts
Diaphragm
Oil Pressure

Sending Unit (Pressure Switch)

Pressure Switch System for Indicating Oil Pressure

104

D: ES-95

ELECTRICAL INDICATOR CIRCUITS
UNIT III

JOB SHEET #1--TEST THE FUEL LEVEL GAUGE SENDING UNIT

I. Tools and materials

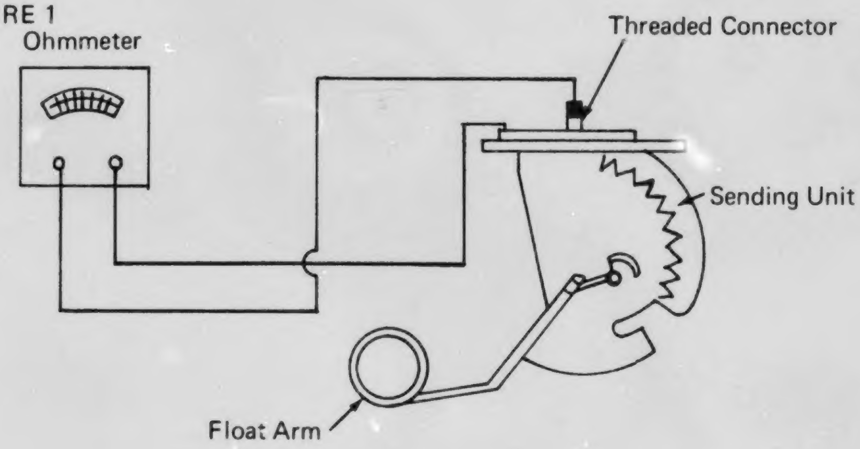
- A. Vehicle
- B. Ohmmeter
- C. Test light
- D. Basic hand tool set
- E. Clean shop towels
- F. Manufacturer's specifications
- G. Appropriate service manual

II. Procedure

(CAUTION: Remove all jewelry before working on any electrical circuit and follow all shop safety procedures.)

- A. Check all wiring connections for opens or grounds
- B. Remove the hold down bolts from the sending unit and remove the sending unit
- C. Connect the ohmmeter to the threaded connector on the sending unit and to the housing (Figure 1)

FIGURE 1



JOB SHEET #1

D. Check the ohmmeter; it should not have a reading with the float arm in the empty position

E. Leave the ohmmeter connected and raise the float arm to the full position; you should now have a measured reading comparable to manufacturer's specifications

(NOTE: Fuel level sending units are not repairable; replace if not within specifications.)

ELECTRICAL INDICATOR CIRCUITS
UNIT III

JOB SHEET #2--CHECK FOR A GROUNDED CIRCUIT

I. Tools and materials

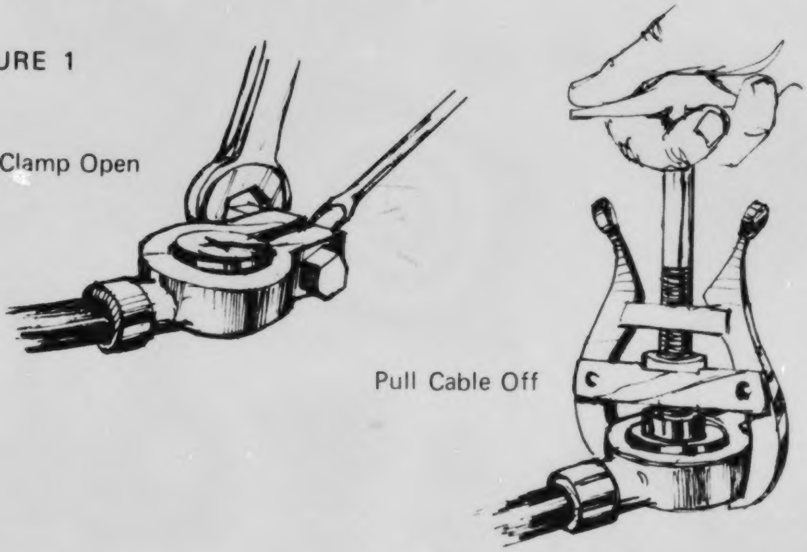
- A. Vehicle
- B. Basic hand tool set
- C. Battery post cleaning tool
- D. Voltmeter
- E. Battery cable puller
- F. Appropriate service manual

II. Procedure

(CAUTION: Remove all jewelry prior to working on any electrical circuit and follow all shop safety procedures.)

- A. Turn off ignition switch
- B. Disconnect clock if so equipped
- C. Remove negative battery cable (Figure 1)

FIGURE 1



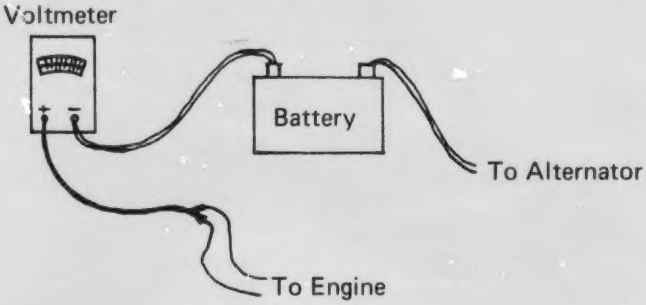
- D. Disconnect vehicle voltmeter if there is one present

JOB SHEET #2

E. Place voltmeter on highest scale; if you do not get a reading, adjust to lower scale

F. Connect voltmeter in series with the battery and battery negative cable (Figure 2)

FIGURE 2


Voltmeter
+
−
Battery
To Alternator
To Engine

G. If voltmeter reads any voltage, pull fuse circuits until there is no reading; that circuit will be the one that is grounded

ELECTRICAL INDICATOR CIRCUITS
UNIT III

NAME ______________________________

TEST

1. Match the terms on the right with their correct definitions.

_____a. Path through which current flows

_____b. Instrument with a graduated scale

_____c. A place, or places, in a conductor that are disconnected or broken

_____d. Where a current carrying conductor contacts another current carrying conductor

_____e. Where a current carrying conductor touches the frame

_____f. Measures current flow

_____g. Measures resistance to current flow

_____h. Gauge that measures voltage or pressure

_____i. A light in the dash that indicates a problem in the system

_____j. The amount of amperage flowing in a circuit

_____k. The amount of potential pressure

_____l. The amount of resistance in a circuit

_____m. Two or more coils of wire that pull the indicator needle

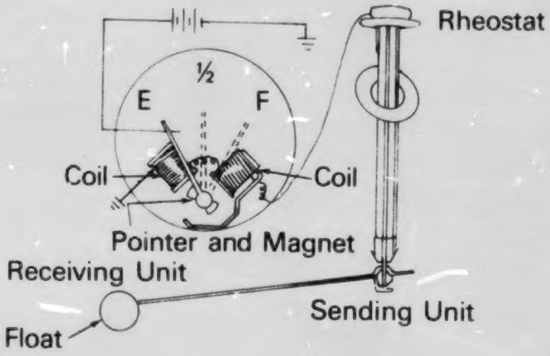
_____n. Regulates voltage from the battery, and charging system to a constant volt output to the indicating devices

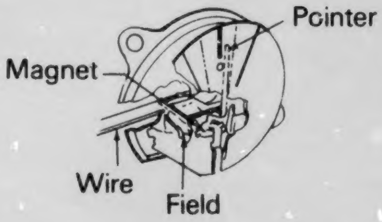
_____o. A wire consisting of two different types of metals welded together that when heated produce a small current flow

_____p. A sensitive voltmeter that measures exhaust temperature

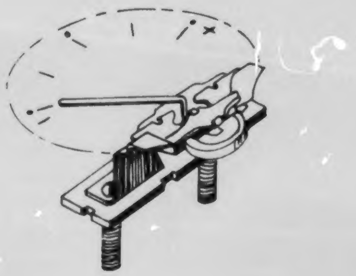
1. Indicator light
2. Voltage
3. Voltmeter
4. Instrument voltage regulator
5. Pyrometer
6. Ground
7. Gauge
8. Conductor
9. Short
10. Open
11. Ohmmeter
12. Ammeter gauge
13. Thermocouple
14. Balancing coil
15. Current
16. Ohm

2. Identify types of gauges by writing the correct answer in the blanks.


Rheostat
½
E
F
Coil
Coil
Pointer and Magnet
Receiving Unit
Sending Unit
Float


Pointer
Magnet
Wire
Field

a. ______________________________ b. ______________________________



c. ______________________________

3. Complete the following list of parts in a gauge circuit.

a. Ammeter gauge

b. ______________________________

c. Temperature gauge

d. Oil pressure gauge

e. ______________________________

f. Pyrometer

g. Sending units

h. ______________________________

i. Wiring that connects the units

j. Instrument voltage regulator

k. Warning light

4. Select true statements concerning the testing procedures for an ammeter gauge by placing an "X" in the appropriate blanks.

   (NOTE: A statement is true only if all parts of the statement are true.)

   _____a. If the ammeter gauge fails to register, use the following testing procedures:

      1. Turn all accessories on and start the engine; the ammeter should indicate a charge

      2. To check the ammeter, stop the engine and turn on the headlights; the ammeter should show a discharge

      3. If it does not show a discharge, replace the ammeter

   _____b. If the ammeter reads in reverse--The wires are crossed on the back connections; disconnect them, reverse them, and reconnect them

5. Complete the following list of procedures for testing a fuel level gauge.

   a. Check all wire ____________________ and wires for opens

   b. Use a sending unit that you know is good or short out the original sending unit

   c. Use an ohmmeter with the following procedures:

      1. Remove the sending unit from the ____________________________

      2. Connect an ohmmeter to the threaded connection and housing; with the float in the empty position you should not have a reading

      3. Now move the float arm to the full position and note the reading

6. Select true statements concerning the procedures for testing a temperature gauge by placing an "X" in the appropriate blanks.

   (NOTE: A statement is true only if all parts of the statement are true.)

   _____a. If temperature gauge fails to register, use the following testing procedures:

      1. Check all wire connections and wires for opens or shorts

      2. Ground the unit and the pointer should start to move; if not, replace the unit

      3. If pointer moves, sending unit is at fault

   _____b. If the temperature gauge registers hot at all times--Grounded wire or unit is at fault

7. Complete the following list of procedures for testing a voltmeter.

   a. If the voltmeter fails to register voltage--Indicates an open in either the wiring or the gauge

   b. If the voltmeter registers in reverse or shows lower than normal system voltage, use the following testing procedures:

      1. Check for grounded system

      2. ____

8. Demonstrate the ability to:

   a. Test the fuel level gauge sending unit.

   b. Check for a grounded circuit.

   (NOTE: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

ELECTRICAL INDICATOR CIRCUITS
UNIT III

ANSWERS TO TEST

1. a. 8
   b. 7
   c. 10
   d. 9
   e. 6
   f. 12
   g. 11
   h. 3
   i. 1
   j. 15
   k. 2
   l. 16
   m. 14
   n. 4
   o. 13
   p. 5

2. a. Balancing coil
   b. Loop type
   c. Moving vane type

3. b. Fuel level gauge
   c. Voltmeter
   h. Resistance units

4. b

5. a. Connections
   c. Tank

6. a, b

7. b. Check battery connections for reversed polarity

8. Performance skills evaluated to the satisfaction of the instructor

STORAGE BATTERIES
UNIT IV

UNIT OBJECTIVE

After completion of this unit, the student should be able to list the functions of a battery and discuss the process by which it converts chemical energy into electrical energy. The student should also be able to select safety rules, explain the term "battery rating", and demonstrate the ability to service and load test a battery. This knowledge will be evidenced by correctly performing the procedures outlined in the job sheets and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to storage batteries with their correct definitions.
2. List three functions of a battery.
3. Match the parts of a battery with their purposes.
4. Select true statements concerning the process by which a battery converts chemical energy into electrical energy during the discharging and charging cycle.
5. Complete a list of statements concerning battery rating.
6. Select safety rules to be observed during the care and maintenance of batteries.
7. Name three characteristics of "service free" batteries.
8. Demonstrate the ability to:
    a. Clean and service a battery.
    b. Remove and replace a battery.
    c. Measure specific gravity of a battery's electrolyte with a hydrometer.
    d. Load test a battery.
    e. Charge test a battery for three minutes.

STORAGE BATTERIES
UNIT IV

SUGGESTED ACTIVITIES

I. Provide student with objective sheet.

II. Provide student with information and job sheets.

III. Make transparencies.

IV. Discuss unit and specific objectives.

V. Discuss information sheet.

VI. Demonstrate and discuss the procedures outlined in the job sheets.

VII. Demonstrate the use of a battery charger.

VIII. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

  A. Objective sheet

  B. Information sheet

  C. Transparency masters

    1. TM 1--Storage Battery Construction
    2. TM 2--Battery Plate Groups
    3. TM 3--Vent Caps
    4. TM 4--Current and Electrolyte

  D. Job sheets

    1. Job Sheet #1--Clean and Service a Battery
    2. Job Sheet #2--Remove and Replace a Battery
    3. Job Sheet #3--Measure Specific Gravity of a Battery's Electrolyte with a Hydrometer
    4. Job Sheet #4--Load Test a Battery
    5. Job Sheet #5--Charge Test a Battery for Three Minutes

E. Test

F. Answers to test

II. References:

A. *Fundamentals of Service: Electrical Systems.* Fourth Edition. Moline, IL: Deere and Company, 1979.

B. Billiet, Walter E., and Goings, Leslie F. *Automotive Electrical Systems.* Third Edition. Chicago: American Technical Society, 1970.

C. Crouse, William H. *Automotive Mechanics.* New York: Webster Division/ McGraw-Hill Book Company, 1975.

D. Dagel, John F. *Diesel Engine Repair.* New York: John Wiley and Sons, Inc., 1982.

E. Foutes, William A. *Diesel Engine Mechanics.* Stillwater, OK: Mid-America Vocational Curriculum Consortium, 1977.

STORAGE BATTERIES
UNIT IV

INFORMATION SHEET

I. Terms and definitions

   A. Battery--Two or more connected cells which convert chemical energy into electrical energy (Transparency 1)

   B. Cell--One positive plate group and one negative plate group (Transparency 2)

   (NOTE: The positive plate contains lead peroxide and the negative plate contains spongy lead.)

   C. Plate group--Similar plates welded to a plate strap (Transparency 2)

   (NOTE: Plate groups are interlaced, with positive and negative plates alternating, but separated to allow free flow of electrolyte.)

   D. Electrolyte--Solution of water and sulfuric acid

   E. Specific gravity--Weight of liquid compared to an equal volume of water at 60°F

   (NOTE: Water has a specific gravity of 1.0.)

   F. Hydrometer--Glass barrel syringe containing a calibrated float used to measure specific gravity

   G. Sulfated--Oxidation of positive plate grid wires and formation of lead sulfate crystals which become dense and hard

   (NOTE: A sulfated condition is caused by long storage without recharging. A slow charge may or may not restore the battery.)

   H. Dissimilar metals--Metals not alike in substance or essentials

II. Functions of the battery

   A. Supplies current for cranking the engine

   B. Supplies current when the demand exceeds the output of the charging system

   C. Stabilizes the voltage in the system during operation

INFORMATION SHEET

III. Purpose of battery parts

A. Plates--Store active material which brings about the chemical reaction to provide electricity

B. Separators--Insulate the negative plates from the positive plates

C. Terminal posts--Connect to conductors for current flow

(NOTE: The positive post is larger than the negative post.)

D. Battery case--Holds the cells and electrolyte to make up the completed battery

E. Vent caps--Close the opening in each cell cover and provide a vent to allow gases to escape (Transparency 3)

F. Cell connector--Connects cells in series

(NOTE: Six-volt batteries have three cells and twelve-volt batteries have six cells connected in series.)

G. Post plate strap--Connects plate groups to terminal posts

IV. Converting chemical energy into electrical energy during the discharging and charging cycle (Transparency 4)

A. Discharging cycle

1. Electrical energy is produced by chemical reaction between the active materials of the dissimilar plates and the sulfuric acid of the electrolyte

2. Lead sulfate is formed at both plates as the battery is discharged, while the sulfuric acid in the electrolyte is replaced by water

B. Charging cycle

1. After the battery is discharged, it must be recharged by a suitable flow of direct current from an external source

2. The specific gravity of the electrolyte increases, sulfuric acid is formed, and water is used up

INFORMATION SHEET

V. Battery rating

   A. Capacity rated according to quantity of electricity that can be taken from a fully charged battery over a definite period of time

      Example: Battery rated at 100 amp-hour should deliver 5 amps continuously for 20 hours

   B. Individual cell amperage depends on total plate area, specific gravity, and temperature of electrolyte

      (NOTE: Battery efficiency drops from 100% at 80°F to 40% at 0°F.)

VI. Safety rules

   A. Wear safety glasses, rubber gloves, and rubber apron when servicing batteries

   B. Electrolyte must not be allowed to come in contact with clothing, skin, eyes, or painted surfaces

   C. Flush immediately with water any area of skin which acid has contacted

   D. Flames or sparks can cause gases given off by battery to explode

      (NOTE: Gases given off are hydrogen and oxygen.)

   E. Avoid shorting or grounding battery terminals during service

   F. Avoid breathing fumes from a battery that is being charged

   G. Leave charger in the "off" position when connecting and disconnecting batteries

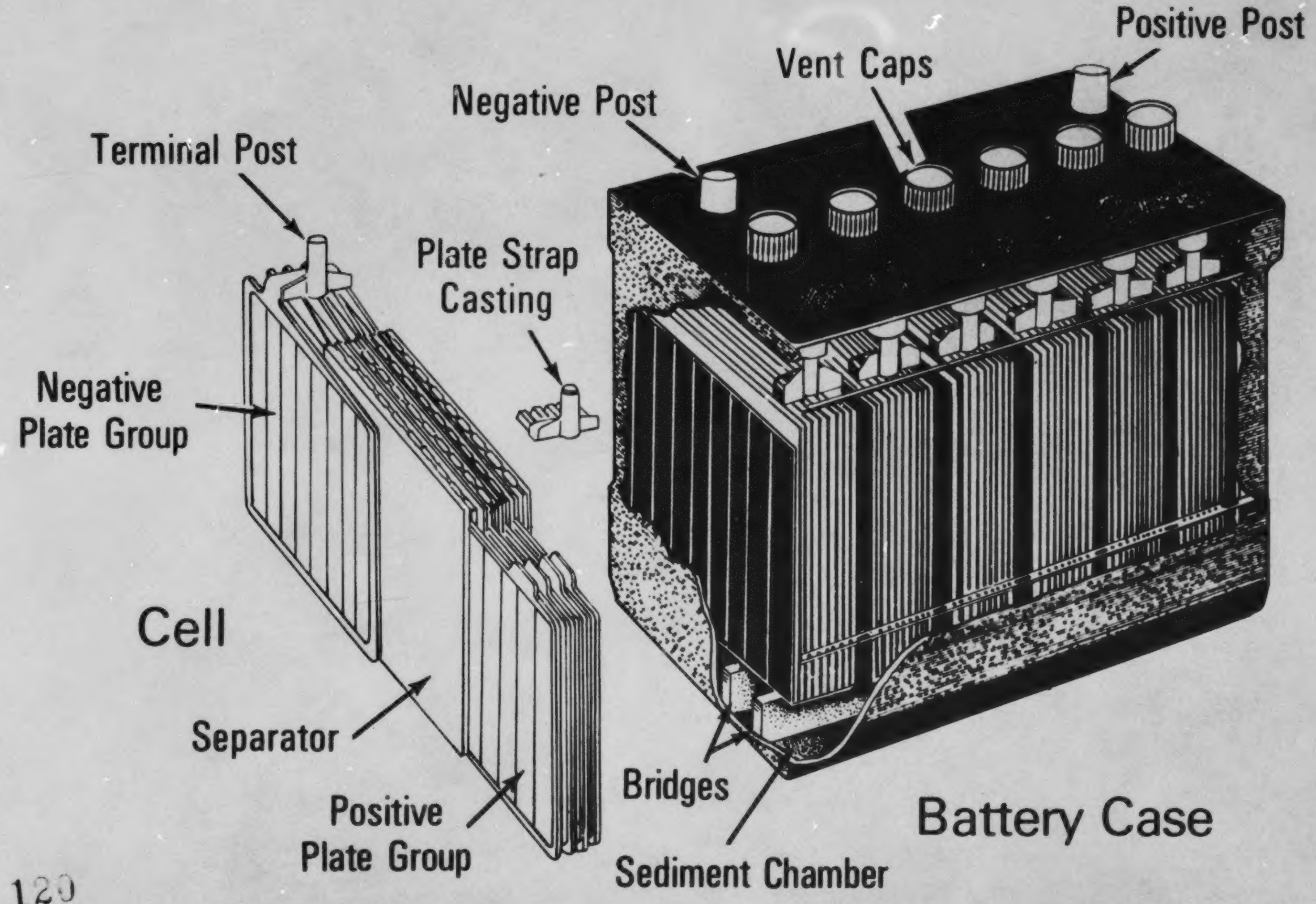
VII. Characteristics of "service free" batteries

   A. Case sealed with lifetime supply of electrolyte

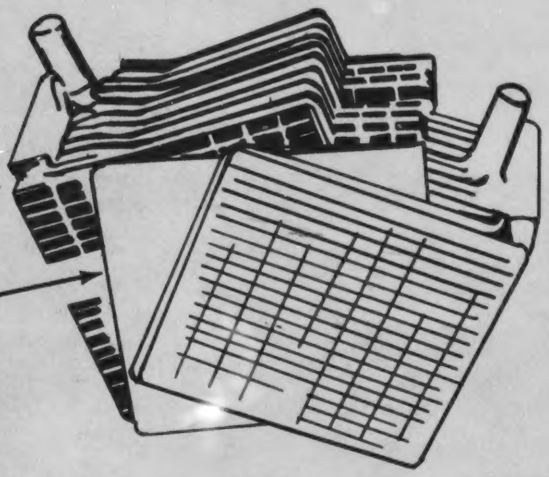
   B. Special liquid-gas separator returns any liquid to reservoir

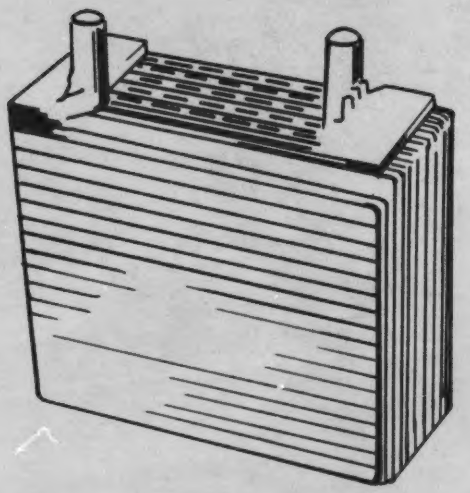
   C. Water loss eliminated through the use of special plates

Storage Battery Construction


Positive Post
Vent Caps
Negative Post
Terminal Post
Plate Strap Casting
Negative Plate Group
Cell
Separator
Positive Plate Group
Bridges
Sediment Chamber
Battery Case

Battery Plate Groups


Positive Plate Group
Separator
Negative Plate Group



Element or Cell

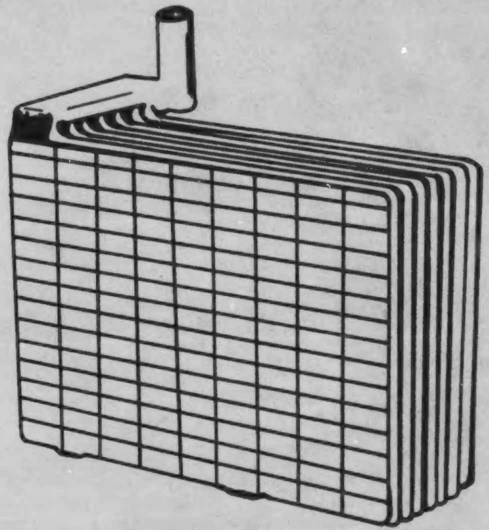
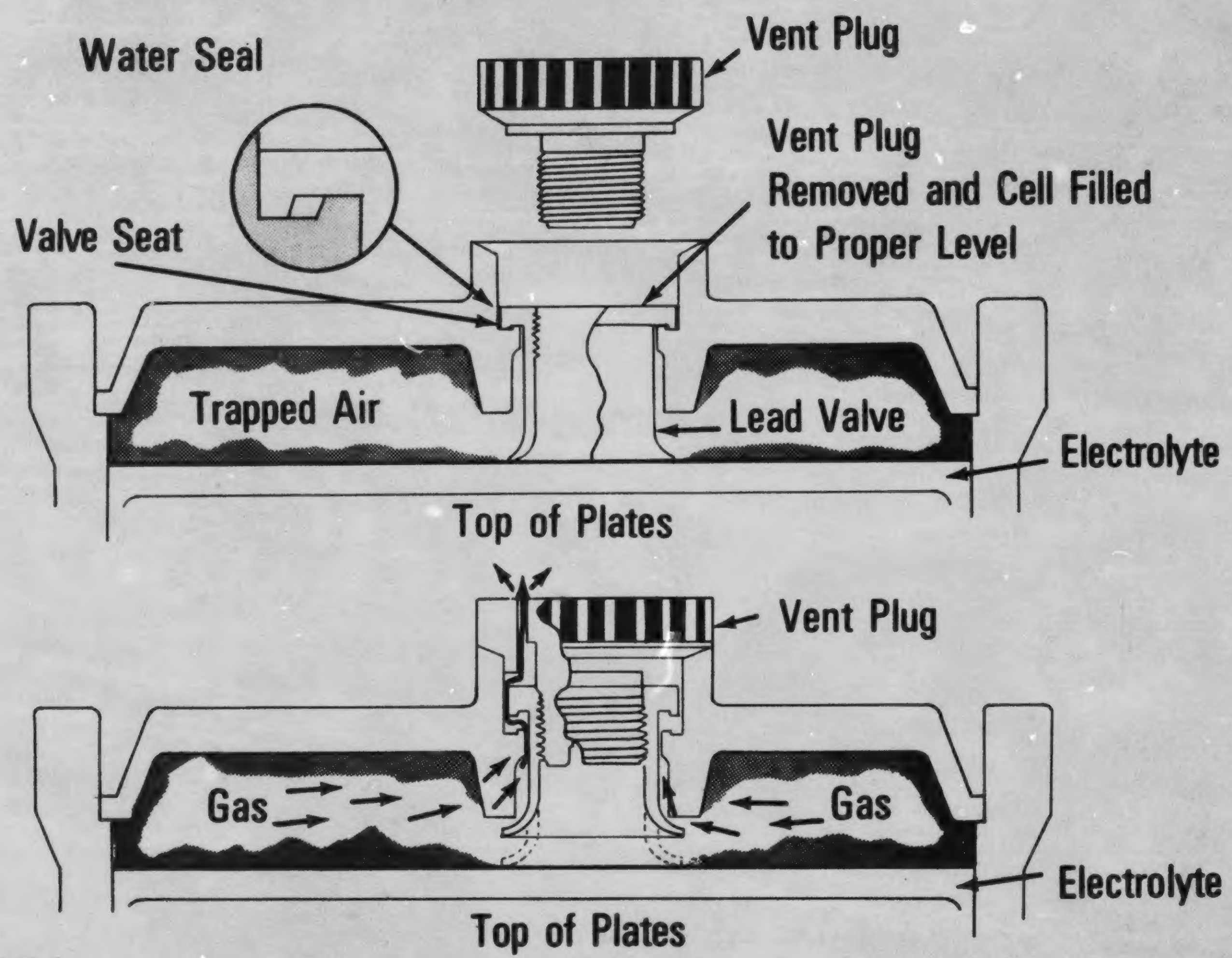


Plate Group

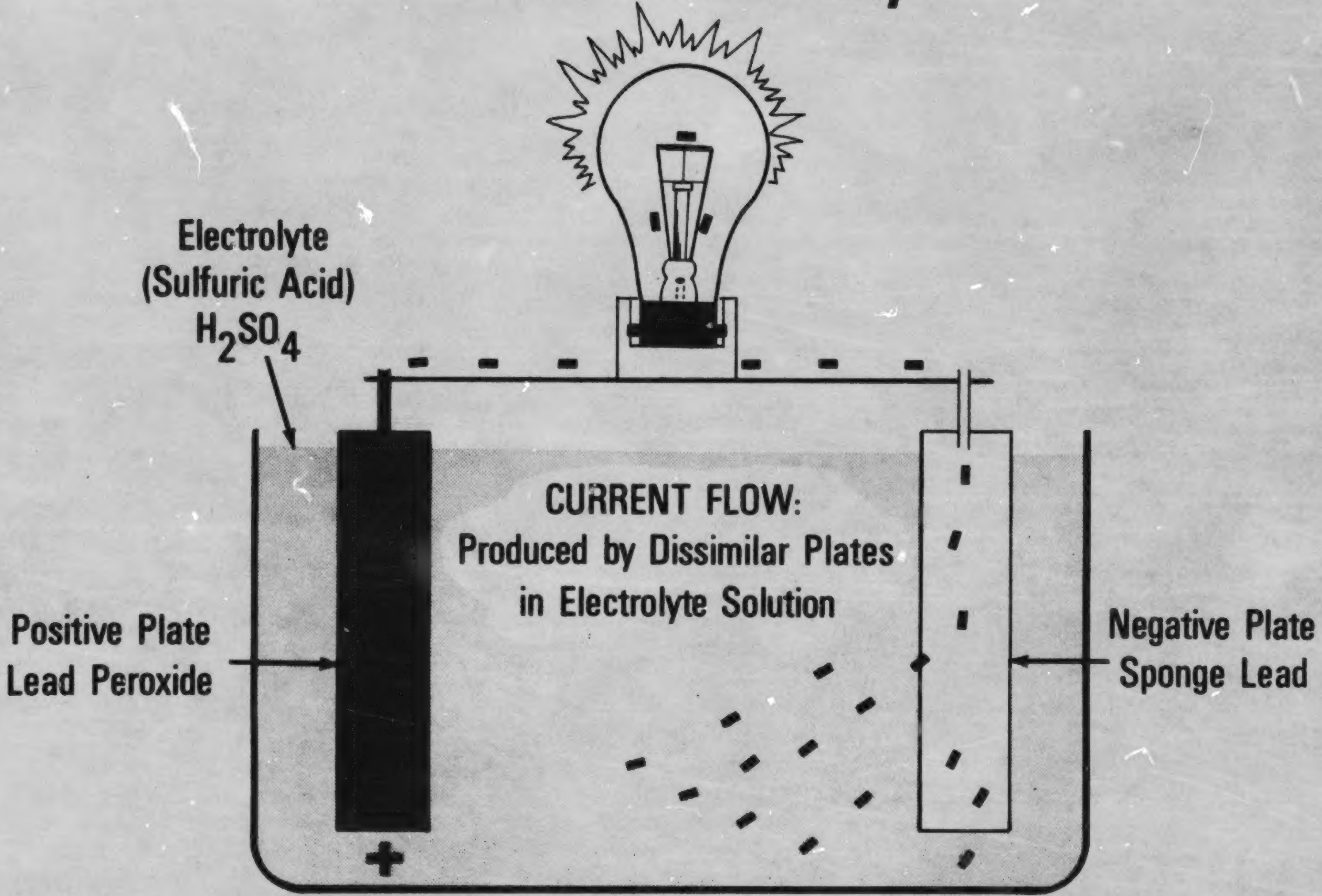
TM 2

D: ES-117

Vent Caps


Water Seal
Vent Plug
Vent Plug Removed and Cell Filled to Proper Level
Valve Seat
Trapped Air
Lead Valve
Electrolyte
Top of Plates
Vent Plug
Gas
Gas
Electrolyte
Top of Plates

Current and Electrolyte


Electrolyte
(Sulfuric Acid)
H_2SO_4
CURRENT FLOW:
Produced by Dissimilar Plates
in Electrolyte Solution
Positive Plate
Lead Peroxide
Negative Plate
Sponge Lead
+

How a Battery Converts Chemical Energy into Electrical Energy

TM 4

D: ES-121

STORAGE BATTERIES
UNIT IV

JOB SHEET #1--CLEAN AND SERVICE A BATTERY

I. Tools and materials

- A. Battery
- B. Safety glasses
- C. Rubber gloves
- D. Rubber apron
- E. Bristle brush
- F. Wire brush
- G. Screwdriver
- H. Battery clamp puller
- I. Combination end wrenches
- J. Battery pliers
- K. Baking soda and water solution (two tablespoons of baking soda to one pint of water)
- L. Battery anti-corrosion paste
- M. Shop towels
- N. Appropriate service manual

II. Procedure

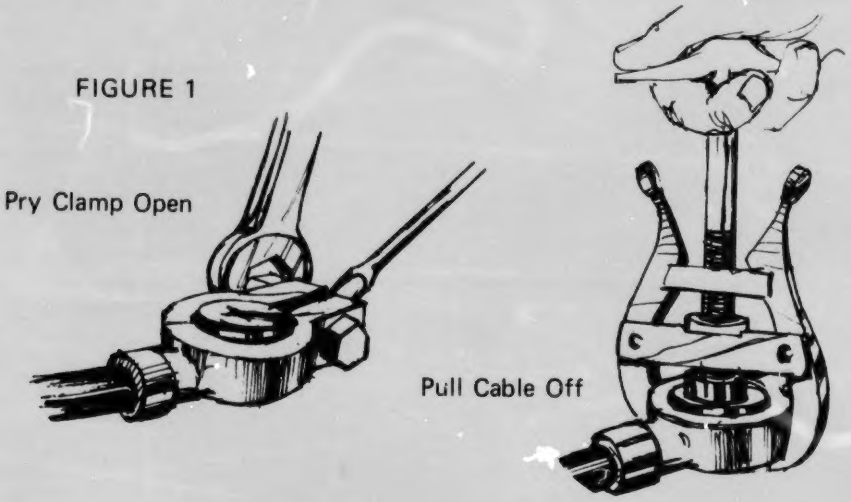
(CAUTION: Remove all jewelry prior to working on any electrical system and follow all shop safety procedures.)

JOB SHEET #1

A. Disconnect battery cables from the battery posts (Figure 1)

(NOTE: Always disconnect the grounded battery cable first to avoid short circuits.)

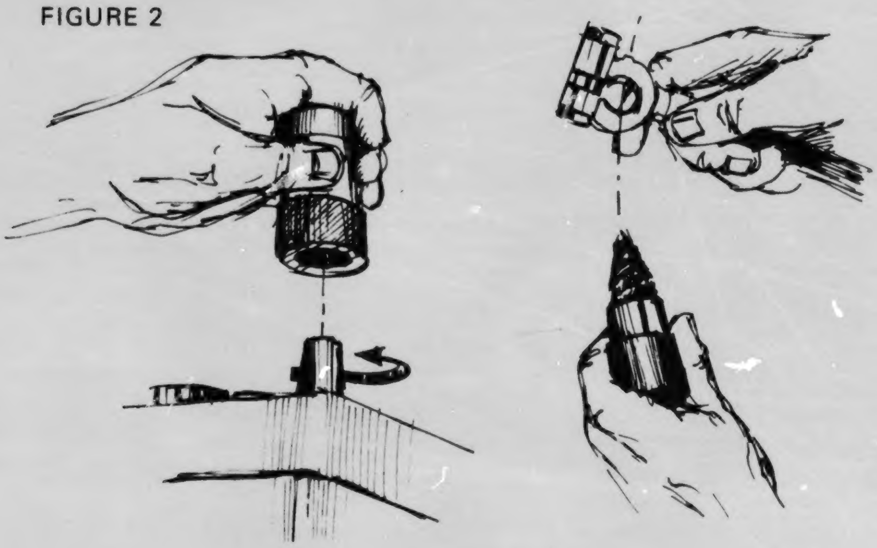
FIGURE 1



B. Clean battery cable clamps and battery post (Figure 2)

(NOTE: Battery posts and inside of battery cable clamps must be clean and bright.)

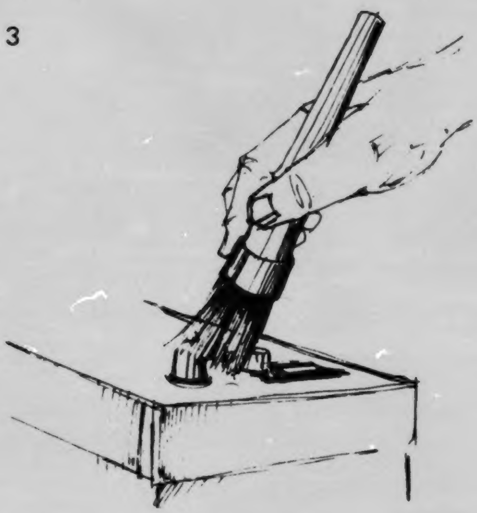
FIGURE 2



JOB SHEET #1

C. Remove loose dirt and corrosion particles from top of battery (Figure 3)

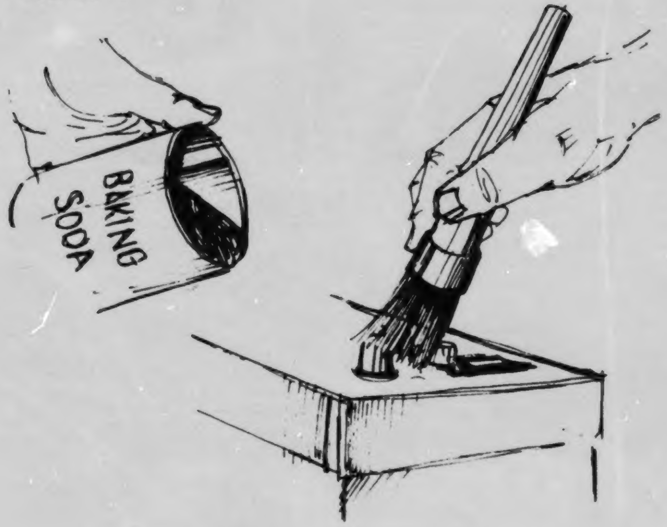
FIGURE 3



D. Brush soda water solution on battery, battery post, clamps, and battery hold-down (Figure 4)

(NOTE: Keep water and soda from entering the battery through the vent holes in the vent caps.)

FIGURE 4



JOB SHEET #1

E. Wash away residue with clean water (Figure 5)

(NOTE: Remove all residue that may have lodged around battery, frame, or parts of the vehicle.)

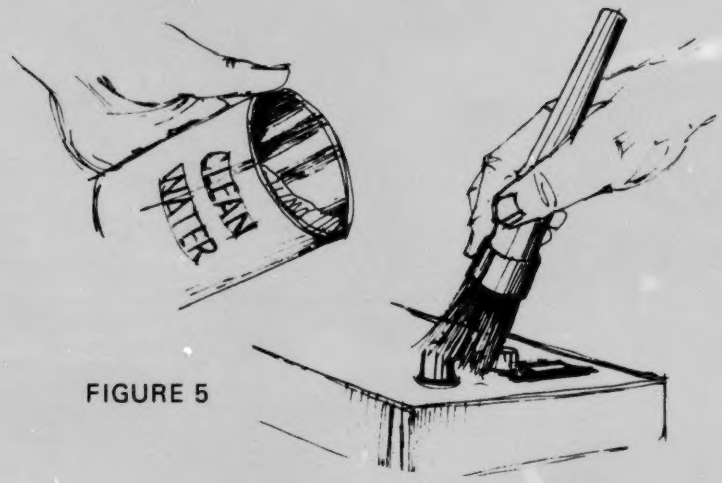


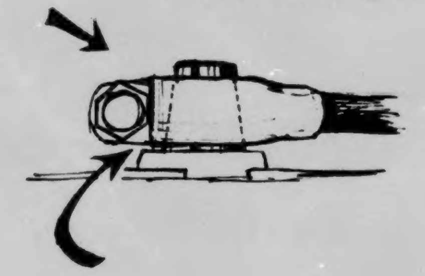
FIGURE 5

F. Dry the battery and battery cables with a clean cloth

G. Reconnect battery cables to the battery posts (Figure 6)

(CAUTION: Always reconnect the power cable first and the ground cable last.)

FIGURE 6



H. Spread a coating of battery anti-corrosion paste over the cable clamps and terminals

I. Remove vent caps and check electrolyte level in all cells

J. Add water if necessary to bring electrolyte up to proper level

(NOTE: Do not overfill.)

STORAGE BATTERIES
UNIT IV

JOB SHEET #2--REMOVE AND REPLACE A BATTERY

I. Tools and materials

- A. Vehicle
- B. Safety glasses
- C. Rubber gloves
- D. Rubber apron
- E. Wire brush
- F. Screwdriver
- G. Battery clamp puller
- H. Combination end wrenches
- I. Battery pliers
- J. Battery cable spreader
- K. Battery post and cable cleaner
- L. Battery lift strap
- M. Appropriate service manual

II. Procedure

(CAUTION: Remove all jewelry prior to working on any electrical system and follow all shop safety procedures.)

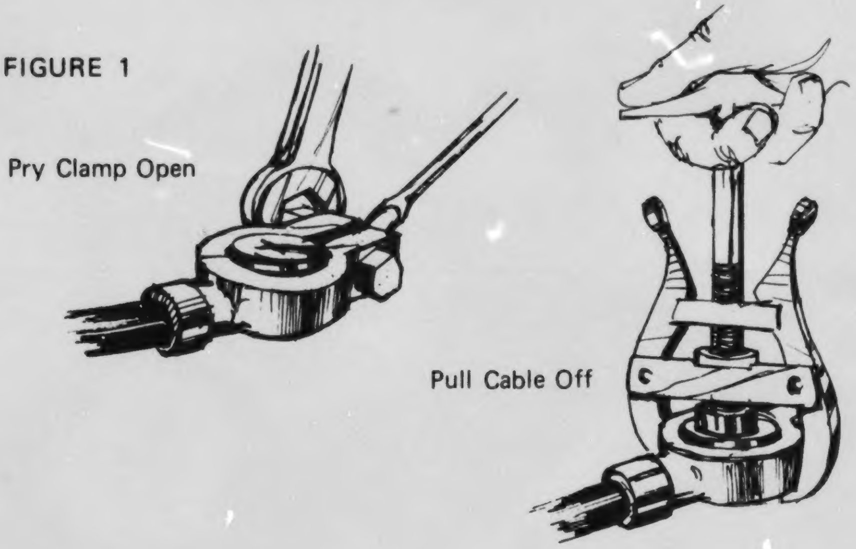
(NOTE: Observe the location of the positive post so the battery can be installed in the same way.)

JOB SHEET #2

A. Disconnect the battery cables from the battery posts (Figure 1)

(NOTE: Always disconnect the grounded battery cable first to avoid short circuits. Use care to avoid twisting the battery cable post.)

FIGURE 1



B. Remove the battery hold-down

C. Remove the battery from the carrier

(NOTE: Use a suitable battery lift strap to lift the battery.)

D. Inspect the battery carrier for dirt or corrosion

(NOTE: Clean with baking soda and water as required.)

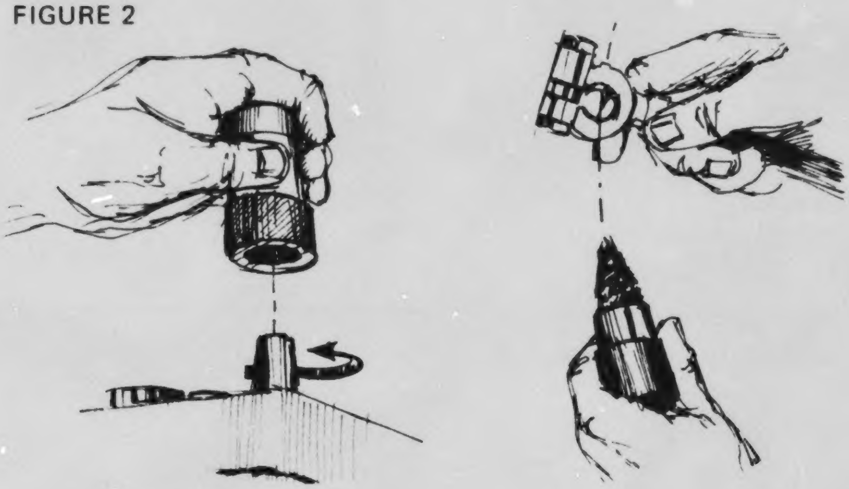
E. Check battery cables for worn or frayed insulation

JOB SHEET #2

F. Clean the inside of battery cables (Figure 2)

(NOTE: Inside of battery cables must be clean and bright.)

FIGURE 2



G. Set the battery into place using a lift strap

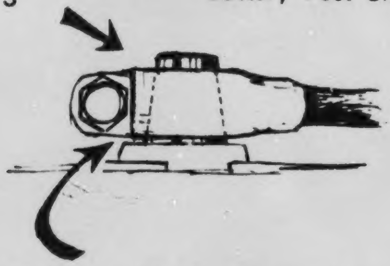
(NOTE: Position the battery to allow for correct battery cable attachment.)

H. Install the battery hold-down clamp or strap and tighten securely

I. Reconnect battery cables to the battery posts (Figure 3)

(NOTE: Always reconnect the power cable first and the ground cable last. Replace clamp bolts and nuts as needed.)

FIGURE 3



Battery Post Slightly Above Clamps

J. Tighten the battery cable clamps securely

(NOTE: Use care to avoid twisting the battery cable post.)

K. Spread a coating of battery anti-corrosion paste over the cable clamps and terminals

STORAGE BATTERIES
UNIT IV

JOB SHEET #3--MEASURE SPECIFIC GRAVITY OF A BATTERY'S ELECTROLYTE WITH A HYDROMETER

I. Tools and materials

  A. Battery
  B. Hydrometer
  C. Shop towels
  D. Container of clean water
  E. Safety glasses
  F. Rubber gloves
  G. Rubber apron
  H. Appropriate service manual

II. Procedure

(CAUTION: Follow all shop safety procedures.)

  A. Remove vent caps from battery
  B. Insert the hydrometer into the first cell
  C. Squeeze the rubber bulb to draw electrolyte into the hydrometer to suspend the float

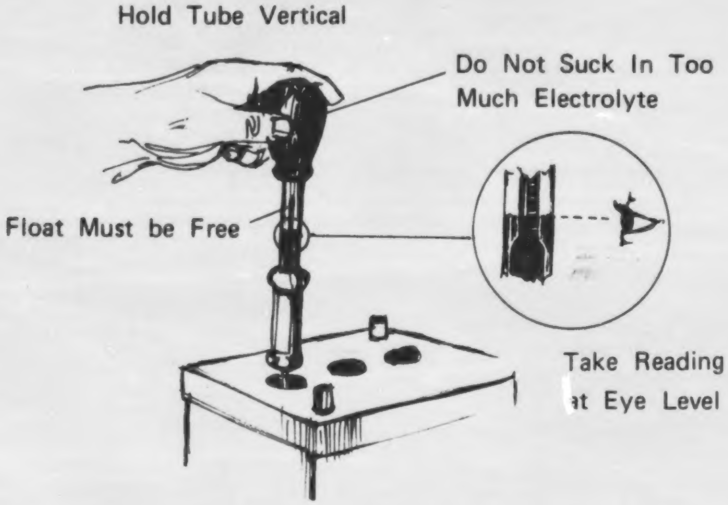
  (NOTE: If the electrolyte level is too low, add water, charge for one hour, and recheck.)

JOB SHEET #3

D. Take reading at eye level (Figure 1)

(NOTE: Make sure the float is not bumping the top of the hydrometer tube or sticking to the side of the tube; write down reading for each cell.)

FIGURE 1


Hold Tube Vertical
Do Not Suck In Too Much Electrolyte
Float Must be Free
Take Reading at Eye Level

E. Squeeze bulb to return electrolyte to cell

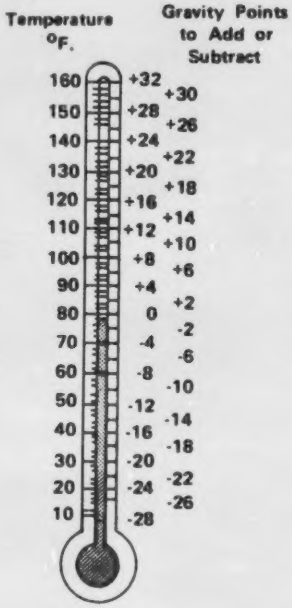
F. Repeat for other cells

JOB SHEET #3

G. Adjust the readings for temperature

1. Add four gravity points (0.004) to the reading for every 10°F above 80°. Subtract four gravity points (0.004) for each 10° below 80°F (Figure 2)

FIGURE 2



TEMPERATURE ADJUSTMENT CHART

2. Check specific gravity; it should read from 1.215 to 1.270 (corrected for 80°F electrolyte temperature)

3. Check the variation in readings between cells; it should be no more than 0.050.

4. Charge and retest the battery if the readings are not within the above mentioned range

H. Replace vent caps upon completion of test

I. Flush any spilled electrolyte with clean water

STORAGE BATTERIES
UNIT IV

JOB SHEET #4--LOAD TEST A BATTERY

I. Tools and materials

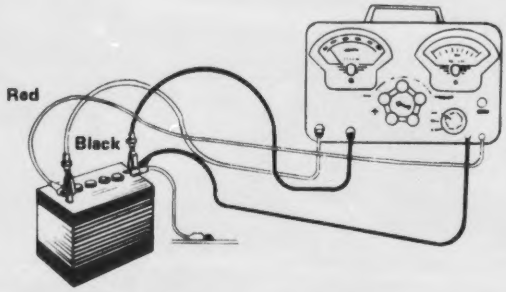
- A. Battery
- B. Battery capacity tester
- C. Appropriate conductors
- D. Safety glasses
- E. Rubber gloves
- F. Rubber apron
- G. Appropriate service manual

II. Procedure

(CAUTION: Remove all jewelry prior to working on any electrical system and follow all shop safety procedures.)

A. Connect tester (Figure 1)

FIGURE 1



BATTERY CAPACITY TEST - 12 VOLT BATTERY

B. Tighten rheostat knob to apply a load to battery

C. Apply load equal to three times the ampere-hour rating of battery being tested

(NOTE: Ampere-hour rating should be marked on the outside of battery case.)

JOB SHEET #4

D. Read battery voltage at the end of 15 seconds

(NOTE: If voltage drops below 1.5 volts per cell in 15 seconds, use the 3-minute charge test.)

E. Loosen rheostat to relieve load at end of 15 seconds

F. Disconnect tester

STORAGE BATTERIES
UNIT IV

JOB SHEET #5--CHARGE TEST A BATTERY FOR THREE MINUTES

I. Tools and materials

   A. Battery

   B. Adjustable, fast rate battery charger

   C. Battery capacity tester

   D. Appropriate conductors

   E. Safety glasses

   F. Rubber gloves

   G. Rubber apron

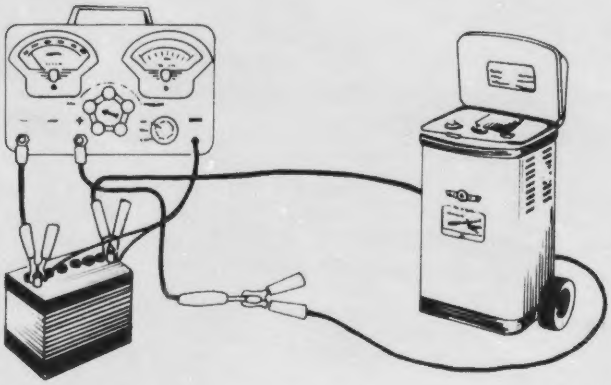
   H. Appropriate service manual

II. Procedure

   (CAUTION: Remove all jewelry prior to working on any electrical system and follow all shop safety procedures.)

   A. Connect tester and charger (Figure 1)

FIGURE 1



BATTERY CHARGE TEST - 12 VOLT BATTERY

   B. Turn charger on and adjust the charging rate to 40 amps

   C. Charge battery for 3 minutes

JOB SHEET #5

D. Read individual cell [illegible]ges with battery charger still in operation

(NOTE: If they vary by more than 0.1 volt (1.10v), replace the battery.)

E. Read total battery voltage

(NOTE: If it is over 15.5v (15 1/2 volts), the battery is unsatisfactory and must be given a long slow charge and load tested again. If voltage under load test is less than 9v, replace battery.)

STORAGE BATTERIES
UNIT IV

NAME ______________________________

TEST

1. Match the terms on the right with their correct definitions.

______a. Two or more connected cells which convert chemical energy into electrical energy

______b. One positive plate group and one negative plate group

______c. Similar plates welded to a plate strap

______d. Solution of water and sulfuric acid

______e. Weight of liquid compared to an equal volume of water at 60°F

______f. Glass barrel syringe containing a calibrated float used to measure specific gravity

______g. Metals not alike in substance or essentials

______h. Oxidation of positive plate grid wires and formation of lead sulfate crystals which become dense and hard

1. Electrolyte
2. Hydrometer
3. Specific gravity
4. Dissimilar metals
5. Battery
6. Plate group
7. Sulfated
8. Cell

2. List three functions of a battery.

a. ____

b. ____

c. ____

3. Match the parts of a battery on the right with their purposes.

_____a. Store active material which brings about the chemical reaction to provide electricity

_____b. Insulate the negative plates from the positive plates

_____c. Connect to conductors for current flow

_____d. Holds the cells and electrolyte to make up the completed battery

_____e. Close the opening in each cell cover and provide a vent to allow gases to escape

_____f. Connects cells in series

_____g. Connects plate groups to terminal posts

1. Terminal posts
2. Battery case
3. Plates
4. Separators
5. Cell connector
6. Vent caps
7. Post plate strap

4. Select true statements concerning the process by which a battery converts chemical energy into electrical energy during the discharging and charging cycle by placing an "X" in the appropriate blanks.

(NOTE: A statement is true only if all parts of a statement are true.)

_____a. Discharging cycle

1) Electrical energy is produced by chemical reaction between the active materials of the dissimilar plates and the sulfuric acid of the electrolyte

2) Lead sulfate is formed at both plates as the battery is discharged, while the sulfuric acid in the electrolyte is replaced by water

_____b. Charging cycle

1) After the battery is discharged, it must be recharged by a suitable flow of direct current from an internal source

2) The specific gravity of the electrolyte increases, water is formed, and sulfuric acid is used up

5. Complete the following list of statements concerning battery rating.

a. Capacity rated according to quantity of electricity that can be taken from a fully charged battery over a definite period of time

b. Individual cell amperage depends on ______________________________

____

6. Select safety rules to be observed during the care and maintenance of batteries by placing an "X" in the appropriate blanks.

   ______a. Electrolyte must not be allowed to come in contact with clothing, skin, eyes, or painted surfaces

   ______b. Flames or sparks can cause gases given off by battery to explode

   ______c. Wear safety glasses, rubber gloves, and rubber apron when servicing batteries

   ______d. Leave charger in the "on" position when connecting and disconnecting batteries

   ______e. Flush immediately with water any area of skin which acid has contacted

   ______f. Avoid breathing fumes from a battery that is being charged

7. Name three characteristics of "service free" batteries.

   a. ____

   b. ____

   c. ____

8. Demonstrate the ability to:

   a. Clean and service a battery.

   b. Remove and replace a battery.

   c. Measure specific gravity of a battery's electrolyte with a hydrometer.

   d. Load test a battery.

   e. Charge test a battery for three minutes.

   (NOTE: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

STORAGE BATTERIES
UNIT IV

ANSWERS TO TEST

1. a. 5 e. 3
   b. 8 f. 2
   c. 6 g. 4
   d. 1 h. 7

2. a. Supplies current for cranking the engine

   b. Supplies current when the demand exceeds the output of the charging system

   c. Stabilizes the voltage in the system during operation

3. a. 3 e. 6
   b. 4 f. 5
   c. 1 g. 7
   d. 2

4. a

5. b. Total plate area, specific gravity, and temperature of electrolyte.

6. a, b, c, e, f

7. a. Case sealed with lifetime supply of electrolyte

   b. Special liquid-gas separator returns any liquid to reservoir

   c. Water loss eliminated through the use of special plates

8. Performance skills evaluated to the satisfaction of the instructor

STARTING CIRCUITS
UNIT V

UNIT OBJECTIVE

After completion of this unit, the student should be able to label the major parts in a starting circuit and match the parts to their functions. The student should also be able to disassemble, test, and reassemble a starter. This knowledge will be evidenced by correctly performing the procedures outlined in the job sheets and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to starting circuits with their correct definitions.
2. Explain the purpose of a starting circuit.
3. Label the major parts in a starting circuit.
4. Match the major parts in a starting circuit with their functions.
5. Name four major parts of a starting motor.
6. Match the component parts of a starting motor with their functions.
7. Explain how a basic starting motor converts electrical energy into mechanical energy.
8. Select true statements concerning how a starting motor is kept running.
9. Discuss the current flow in a starting motor circuit.
10. Identify four types of starter field circuits.
11. Match the types of starter field circuits with the current flow in each type circuit.
12. Select true statements concerning counter electromotive force in relation to armature speed.
13. Name four types of switches for starting motors.
14. Distinguish between a magnetic switch and a solenoid switch.
15. Arrange in order the steps in the operation of a series-parallel switch.
16. Explain two ways starter drives are engaged.

17. List three types of electromagnetic or lever shift drives.

18. Demonstrate the ability to:

    a. Remove and replace a starter.

    b. Disassemble, test, and reassemble a starter.

    c. Test starter circuit (no load).

    d. Recondition starting motor armature.

    e. Check voltage drop in a starter circuit.

STARTING CIRCUITS
UNIT V

SUGGESTED ACTIVITIES

I. Provide student with objective sheet.

II. Provide student with information and job sheets.

III. Make transparencies.

IV. Discuss unit and specific objectives.

V. Discuss information sheet.

VI. Demonstrate and discuss the procedures outlined in the job sheets.

VII. Demonstrate different designs of starters.

VIII. Take field trip to a starter rebuilding shop.

IX. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

  A. Objective sheet

  B. Information sheet

  C. Transparency masters

    1. TM 1--Starter Motor Component Parts
    2. TM 2--Components of Armature
    3. TM 3--Parts in Starting Circuit
    4. TM 4--Starting Motor
    5. TM 5--Starter Field Circuits
    6. TM 6--Types of Motor Switches
    7. TM 7--Series-Parallel Switch and Starter Circuit
    8. TM 8--Types of Electromagnetic or Lever Shift Drives

D. Job sheets

  1. Job Sheet #1--Remove and Replace a Starter
  2. Job Sheet #2--Disassemble, Test, and Reassemble a Starter
  3. Job Sheet #3--Test Starter Circuit (No Load)
  4. Job Sheet #4--Recondition Starting Motor Armature
  5. Job Sheet #5--Check Voltage Drop in a Starter Circuit

E. Test

F. Answers to test

II. References:

A. *Fundamentals of Service: Electrical Systems.* Fourth Edition. Moline, IL: Deere and Company, 1979.

B. Billiet, Walter E. and Goings, Leslie F. *Automotive Electrical Systems.* Third Edition. Chicago, IL: American Technical Society, 1970.

C. Crouse, William H. *Automotive Mechanics.* New York: Webster Divison/ McGraw-Hill Book Company, 1975.

D. Dagel, John F. *Diesel Engine Repair.* New York: John Wiley and Sons, Inc., 1972.

E. Foutes, William A. *Diesel Engine Mechanics.* Stillwater, OK: Mid-America Vocational Curriculum Consortium, 1977.

STARTING CIRCUITS
UNIT V

INFORMATION SHEET

I. Terms and definitions (Transparencies 1 and 2)

  A. Pole pieces--Ends of a magnet in the field frame assembly of a starting motor

  B. Field winding--Wire wrapped around pole pieces to increase the strength of the magnetic field when current is passed through the windings

  C. Armature--Main drive of starter motor; converts electrical energy into mechanical energy

  D. Commutator--Metal segments attached to ends of wire loops to form contact surface on armature

  E. Brushes--Sliding contacts to feed electrical energy from battery to commutator

  F. Pinion--Small gear that meshes with a larger gear

  G. Solenoid--Electromagnetic switch that closes circuit and engages the motor drive pinion with the flywheel

  H. Motor switch--Manual, magnetic, or solenoid switch

  I. Inertia--Tendency of a body in motion to remain in motion

  J. Cemf --Counter electromotive force

  K. Voltage drop--The drop, or current used in cables

II. Purpose of a starting circuit--Converts electrical energy from the battery into mechanical energy at the starting motor to crank the engine (Transparency 3)

III. Major parts in a starting circuit (Transparency 3)

  A. Battery

  B. Starter switch

  C. Motor switch

  D. Starting motor

INFORMATION SHEET

IV. Function of parts of a starting circuit

   A. Battery--Supplies energy for the circuit

   B. Starter switch--Activates the circuit

   C. Motor switch--Closes circuit to motor and engages motor drive with flywheel

   D. Starting motor--Drives flywheel to start engine

V. Major parts of a starting motor (Transparencies 1 and 4)

   A. Motor switch

   B. Field frame assembly

   C. Armature

   D. Drive mechanism

VI. Component parts and their functions (Transparency 4)

   A. Pole shoe--Forms a magnetic field of force around armature

   B. Field winding--Wrapped around pole shoe to strengthen magnetic field when current is passed through the winding

   C. Armature--Converts electrical energy into mechanical energy to drive mechanism to crank engine

   (NOTE: The magnetic field around the loop and the field between the pole shoes repel each other causing the loop or armature to turn.)

   D. Commutator--Forms contact surface for battery to feed electrical current through armature

   E. Brushes--Sliding contacts which feed electrical energy to the commutator

VII. Conversion of electrical energy into mechanical energy--Current carrying conductor (armature) formed in a loop and mounted on a shaft, will cause the shaft to rotate when placed inside a magnetic field (field windings)

VIII. How a starting motor is kept running (Transparency 2)

   A. The magnetic field around the armature and the magnetic field between the pole pieces repel each other causing the armature to turn

INFORMATION SHEET

B. Metal segments on the ends of the commutator make a one-half turn reversing their connection through sliding contacts (brushes) which causes the current to flow in the opposite direction in the armature windings

IX. Current flow in a starting motor circuit--Current will flow from battery, through cable, across switch contacts, through field windings and armature, and back to battery through ground (Transparency 3)

X. Types of starter field circuits (Transparency 5)

A. Series-wound

B. Parallel-wound

C. Series-parallel-wound

D. Compound-wound

XI. Types of starter field circuits and current flow (Transparency 5)

A. Series-wound--Current flows through all the field windings before it flows through the two insulated brushes to the armature

B. Parallel-wound--Current flows through one field winding to the brushes, and also through the other field winding to the brushes, placing the field windings in parallel

C. Series-parallel-wound--One third of the current flows through each pair of field windings to one of the three insulated brushes

D. Compound-wound--One or more of the poles is shunt wound, connected directly to ground to prevent excessive speeds

(NOTE: The shunt coil is not affected by the counter voltage (CEMF) induced into the armature windings when passing through the magnetic field of the field coils.)

XII. Counter electromotive force in relation to armature speed

A. Counter voltage (cemf) is induced into the armature windings when they pass through the magnetic field of the field coils

B. The faster the armature turns the higher the counter voltage

C. The compound-wound starter shunt winding prevents excessive speeding because the shunt winding is connected directly to ground, reducing the series field winding, armature current flow, and armature free speed

INFORMATION SHEET

XIII. Types of switches for starting motors (Transparencies 6 and 7)

- A. Manual
- B. Solenoid
- C. Magnetic
- D. Series-parallel

XIV. Magnetic and solenoid switches (Transparency 6)

- A. Magnetic--Normally used with bendix drive as switch does not provide mechanical shifting of drive mechanism
- B. Solenoid--Provides a mechanical means of shifting pinion into mesh with flywheel

XV. Operation of a series-parallel switch (Transparency 7)

- A. Starter switch closes, connecting two 12 volt batteries in series with the starting motor
- B. Solenoid circuit is completed by a set of points mechanically closed by the series-parallel switch plunger and starter turns over
- C. Starter switch is released, going into neutral position, permitting operation of electrical equipment by two 12 volt batteries in parallel for normal operation

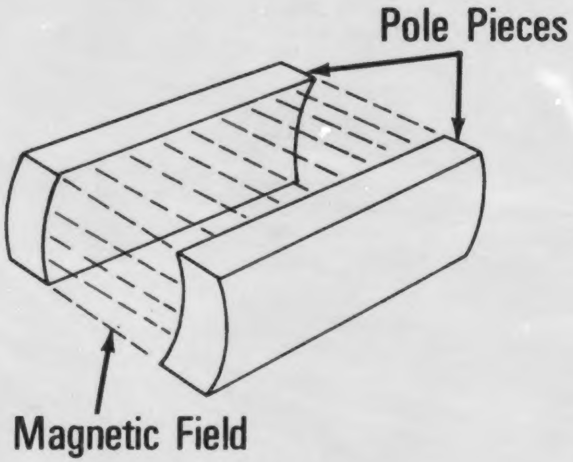
XVI. Engaging starter drives

- A. Inertia of armature acting through drive mechanism
- B. Electromagnetic plunger to mechanically shift pinion into mesh

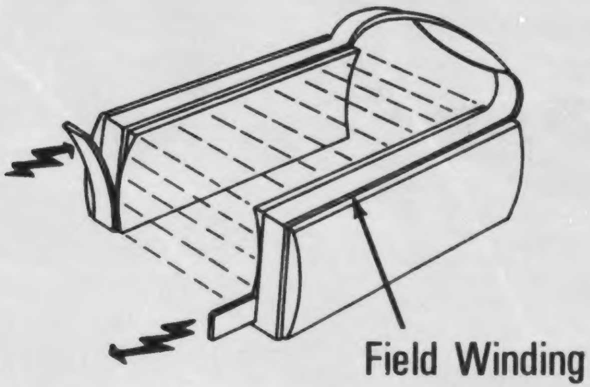
XVII. Types of electromagnetic or lever shift drives (Transparency 8)

- A. Overrunning clutch
- B. Dyer drive
- C. Sprag clutch drive

Starter Motor Component Parts

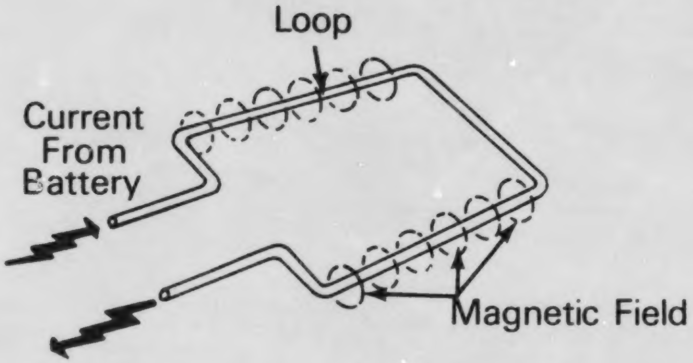

Pole Pieces
Magnetic Field

POLE PIECES AND THEIR MAGNETIC FIELD

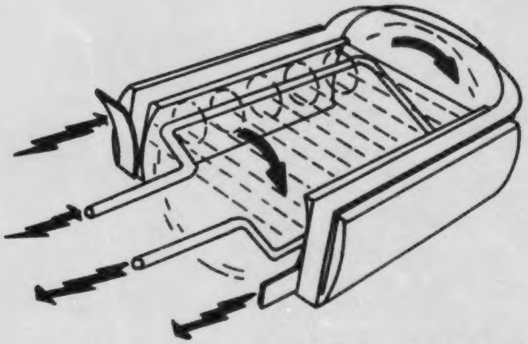

Field Winding

FIELD WINDING ADDED TO POLE PIECES

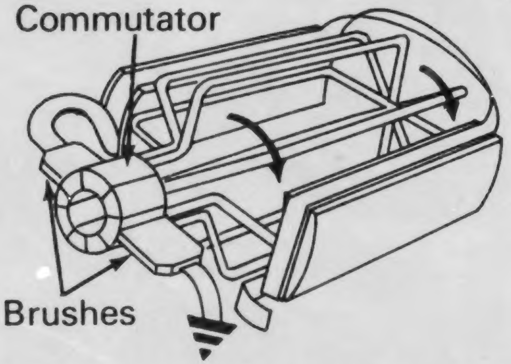
Components of Armature


Loop
Current
From
Battery
Magnetic Field

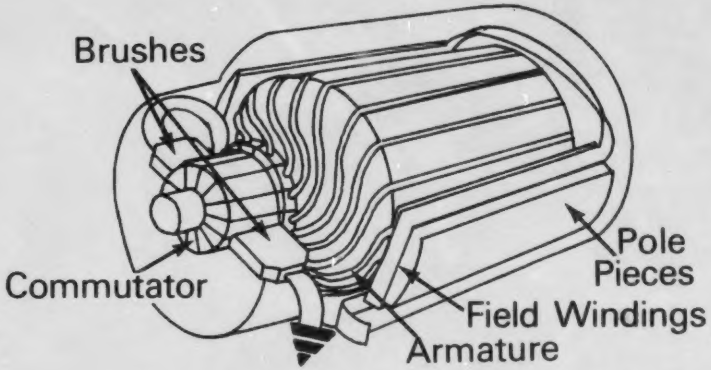
LOOP OF "LIVE" WIRE AND ITS MAGNETIC FIELD



LOOP PLACED IN FIELD WINDINGS

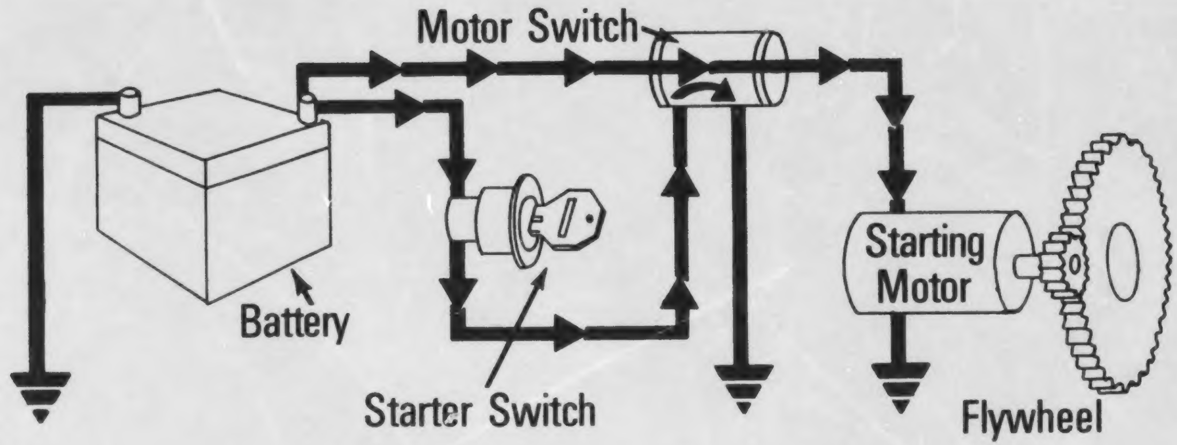

Commutator
Brushes

ARMATURE FOR STARTING MOTOR

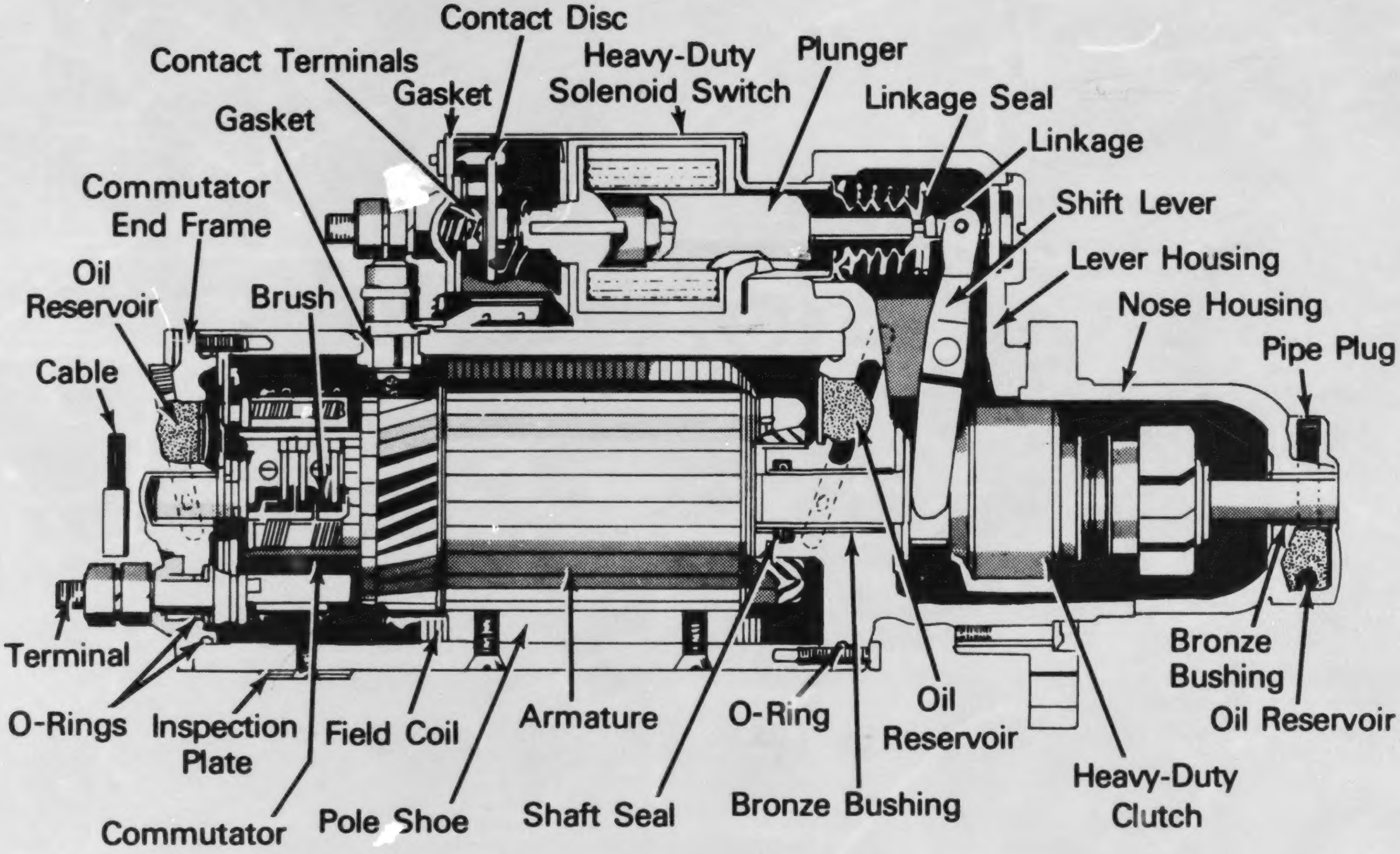

Brushes
Commutator
Pole
Pieces
Field Windings
Armature

ARMATURE AND BRUSHES

Parts in Starting Circuit


Motor Switch
Battery
Starter Switch
Starting Motor
Flywheel

Starting Motor


Contact Disc
Contact Terminals
Gasket
Heavy-Duty Solenoid Switch
Plunger
Linkage Seal
Gasket
Linkage
Commutator End Frame
Shift Lever
Lever Housing
Oil Reservoir
Brush
Nose Housing
Pipe Plug
Cable
Terminal
Bronze Bushing
O-Rings
Inspection Plate
Field Coil
Armature
O-Ring
Oil Reservoir
Oil Reservoir
Heavy-Duty Clutch
Commutator
Pole Shoe
Shaft Seal
Bronze Bushing

TM 4

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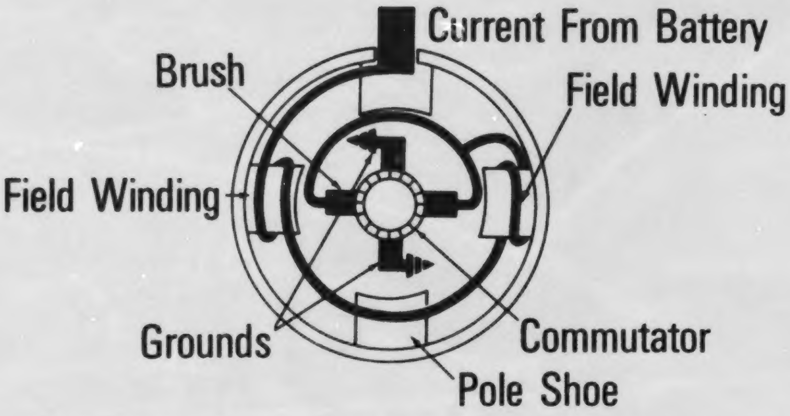
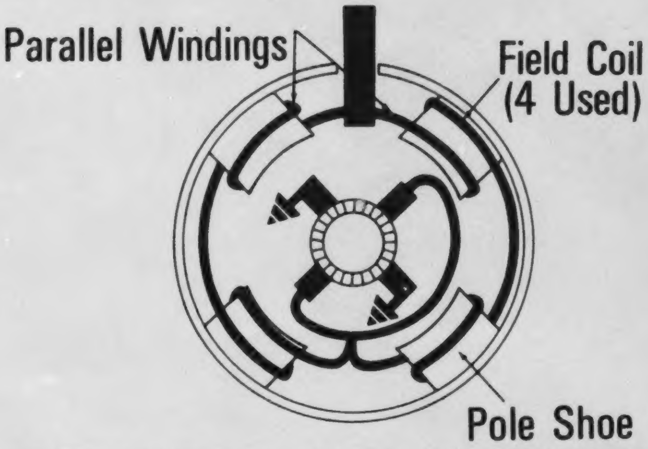
D: ES-159

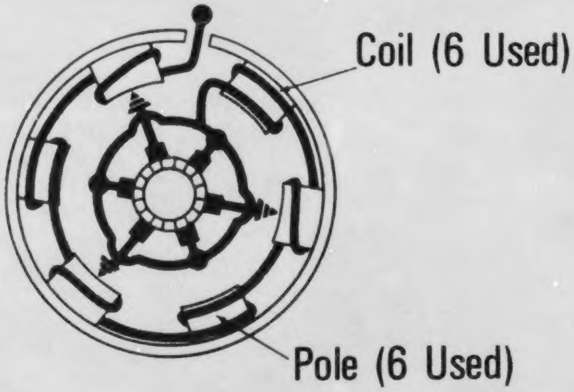
Starter Field Circuits


Current From Battery
Brush
Field Winding
Field Winding
Grounds
Commutator
Pole Shoe

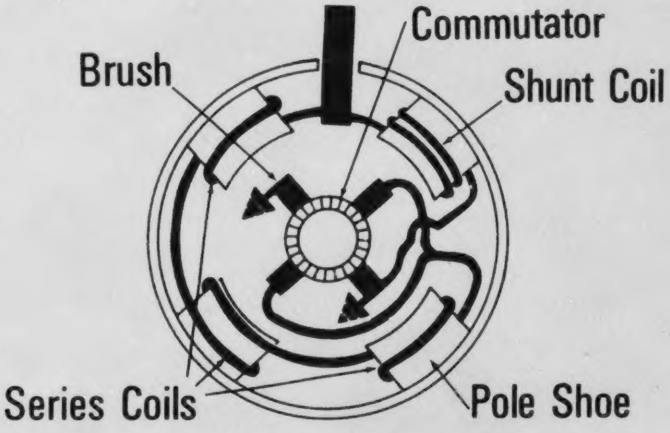
FOUR-POLE –TWO-COIL SERIES-WOUND MOTOR


Parallel Windings
Field Coil
(4 Used)
Pole Shoe

FOUR-POLE—FOUR-COIL PARALLEL-WOUND MOTOR

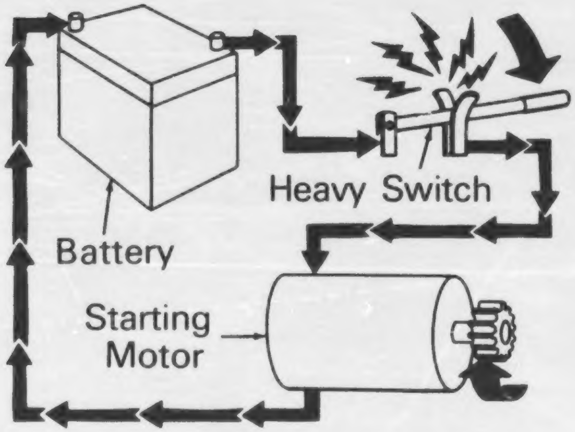

Coil (6 Used)
Pole (6 Used)

SIX-POLE—SIX-COIL SERIES-PARALLEL-WOUND MOTOR

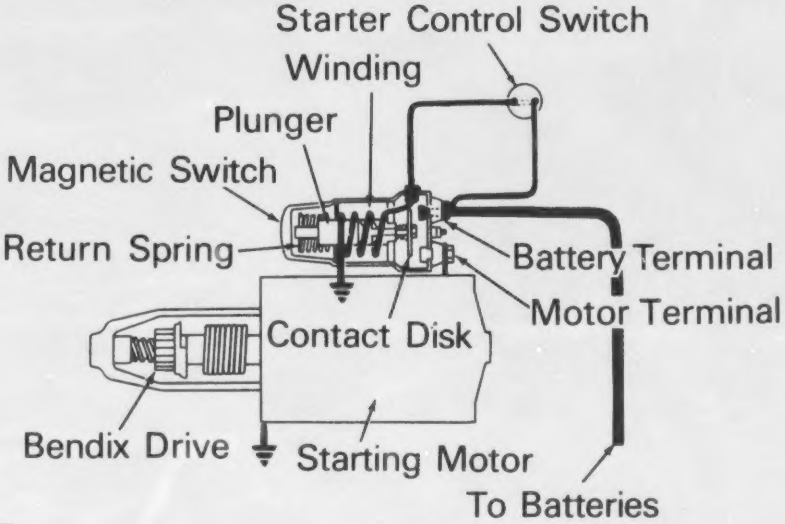

Commutator
Brush
Shunt Coil
Series Coils
Pole Shoe

COMPOUND-WOUND MOTOR

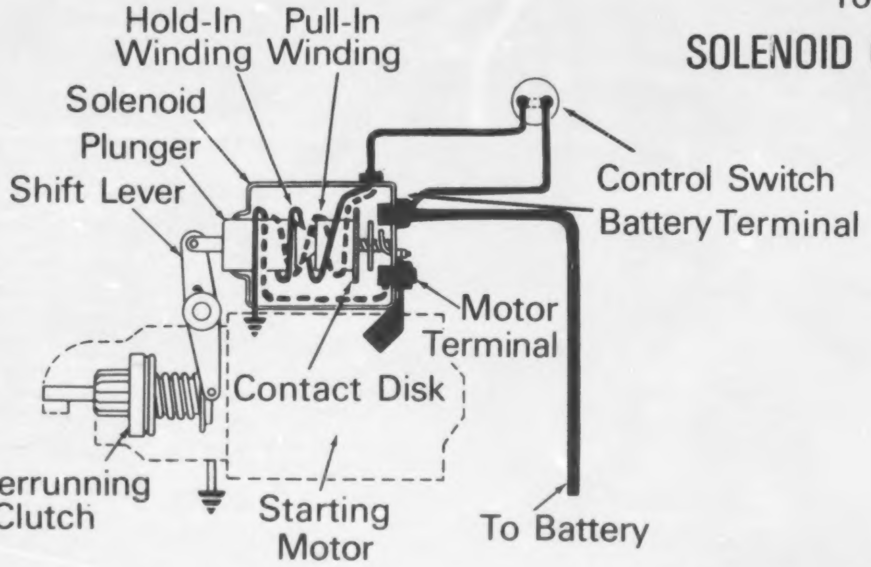
Types of Motor Switches


Heavy Switch
Battery
Starting Motor

MANUAL SWITCH

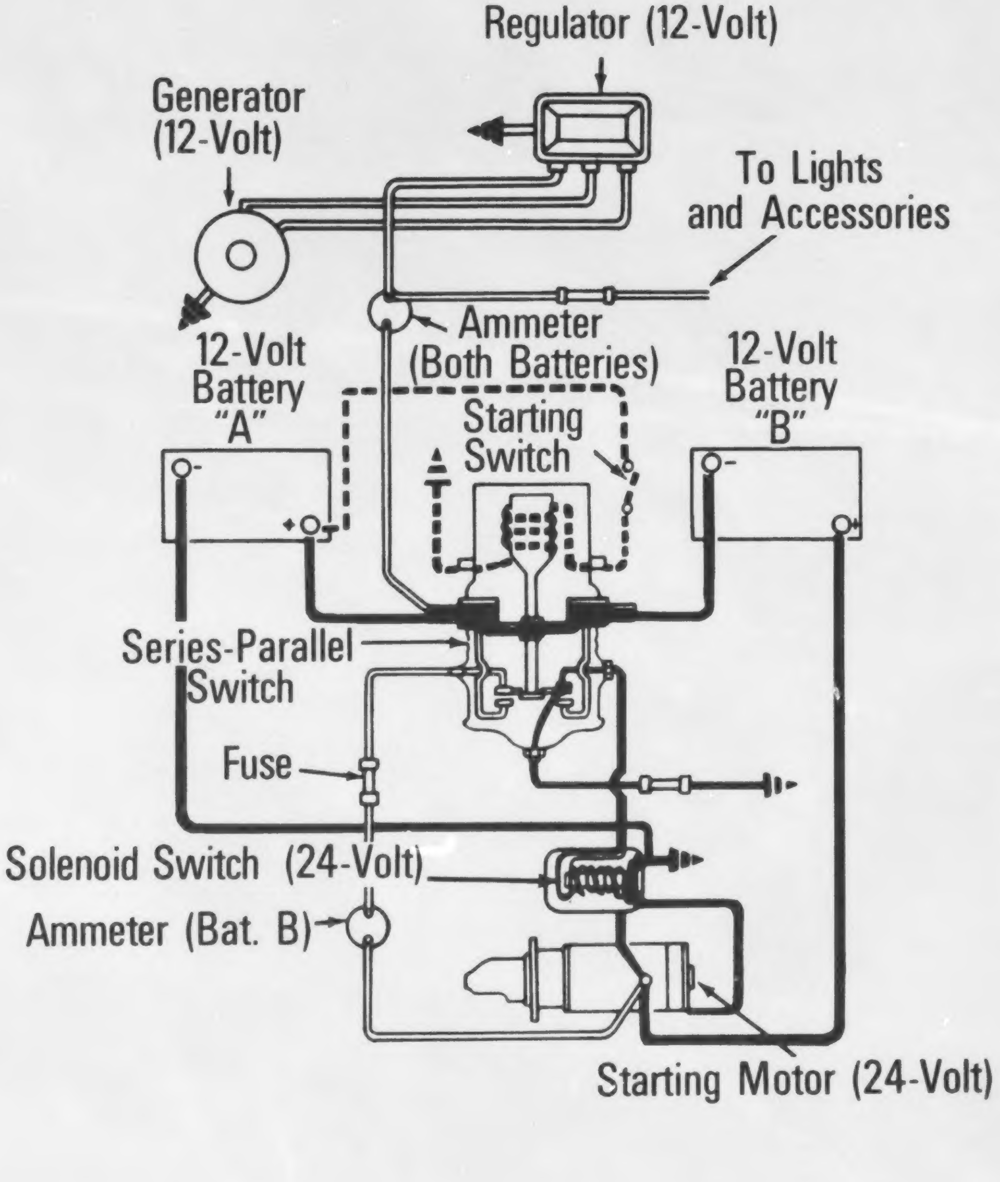

Starter Control Switch
Winding
Plunger
Magnetic Switch
Return Spring
Battery Terminal
Motor Terminal
Contact Disk
Bendix Drive
Starting Motor
To Batteries

SOLENOID CIRCUIT

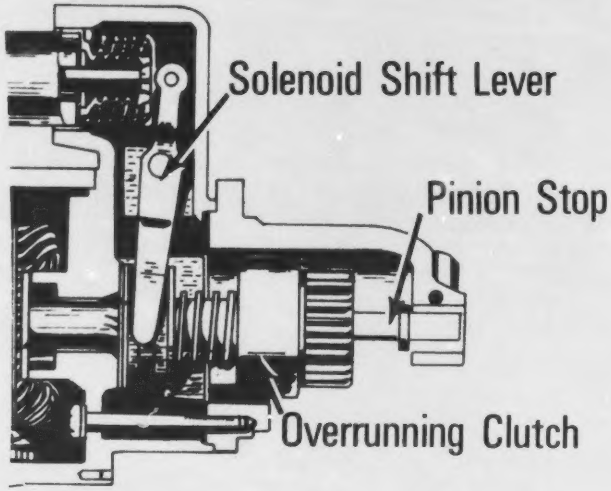

Hold-In Winding
Pull-In Winding
Solenoid
Plunger
Shift Lever
Control Switch
Battery Terminal
Motor Terminal
Contact Disk
Overrunning Clutch
Starting Motor
To Battery

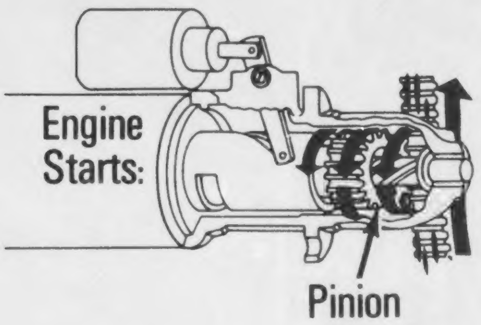
TYPICAL MAGNETIC SWITCH CIRCUIT

Series-Parallel Switch and Starter Circuit

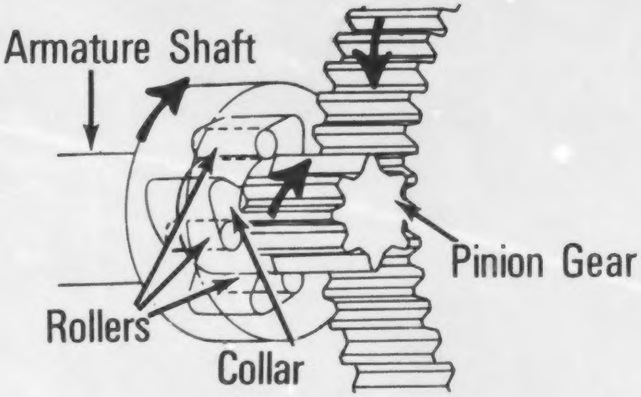

Regulator (12-Volt)
Generator (12-Volt)
To Lights and Accessories
Ammeter (Both Batteries)
12-Volt Battery "A"
12-Volt Battery "B"
Starting Switch
Series-Parallel Switch
Fuse
Solenoid Switch (24-Volt)
Ammeter (Bat. B)
Starting Motor (24-Volt)

Types of Electromagnetic or Lever Shift Drives

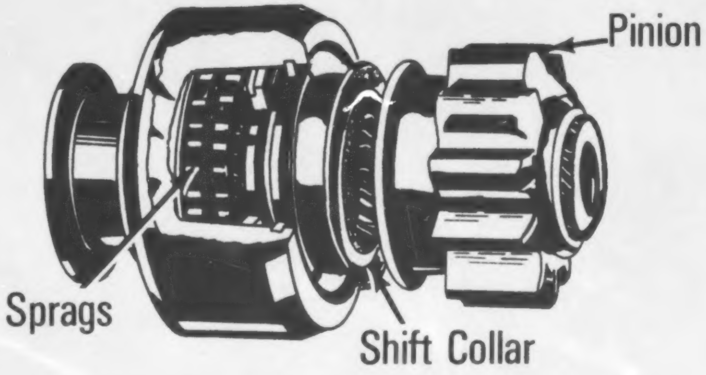

Solenoid Shift Lever
Pinion Stop
Overrunning Clutch


Engine Starts:
Pinion

DYER DRIVE IN OPERATION: 3) FLYWHEEL SPINNING PINION OUT OF MESH


Armature Shaft
Pinion Gear
Rollers
Collar

OVERRUNNING CLUTCH DRIVE ENGAGED


Pinion
Sprags
Shift Collar

SPRAG CLUTCH DRIVE

STARTING CIRCUITS
UNIT V

JOB SHEET #1--REMOVE AND REPLACE A STARTER

I. Tools and materials

   A. Vehicle
   B. Combination end wrenches, 3/8" - 3/4"
   C. Sockets, 3/8" - 3/4" by 3/8" drive
   D. Ratchet, 3/8" drive
   E. Extensions, 3" and 6" by 3/8" drive
   F. Small ignition wrench set
   G. Battery cable pliers
   H. Safety glasses
   I. Appropriate service manual

II. Procedure

(CAUTION: Remove all jewelry prior to working on any electrical system and follow all shop safety procedures.)

A. Remove starter

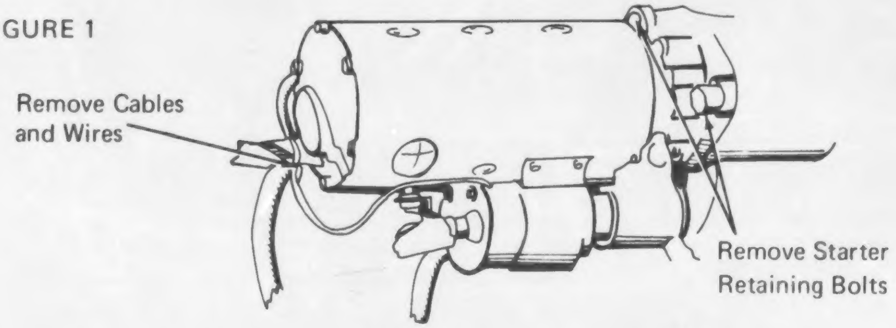
1. Disconnect battery ground cable

2. Remove the cables and electrical wires from the starter

   (NOTE: In some cases it may be necessary to remove the starter retaining bolts and allow the starter to be lowered to provide easy removal of the starter wires and cables.)

3. Remove starter retaining bolts as required (Figure 1)

FIGURE 1



JOB SHEET #1

4. Remove other starter brackets if used
5. Remove starter from engine

   (CAUTION: Starter motors are heavy and should be handled carefully during removal to avoid damage to the starter or injury to the worker.)

B. Replace starter

1. Clean starter and block mounting surfaces
2. Position starter in mounting position and start retaining bolts
3. Tighten starter retaining bolts securely
4. Position starter wires and cables in place and start retaining nuts
5. Tighten starter wires and retaining nuts securely

   (NOTE: Avoid overtightening and twisting off small retaining nuts.)

6. Replace any brackets that may have been removed and tighten securely
7. Check all connections
8. Replace battery ground cable
9. Start engine two or three times to check starter action

STARTING CIRCUITS
UNIT V

JOB SHEET #2--DISASSEMBLE, TEST, AND REASSEMBLE A STARTER

I. Tools and materials

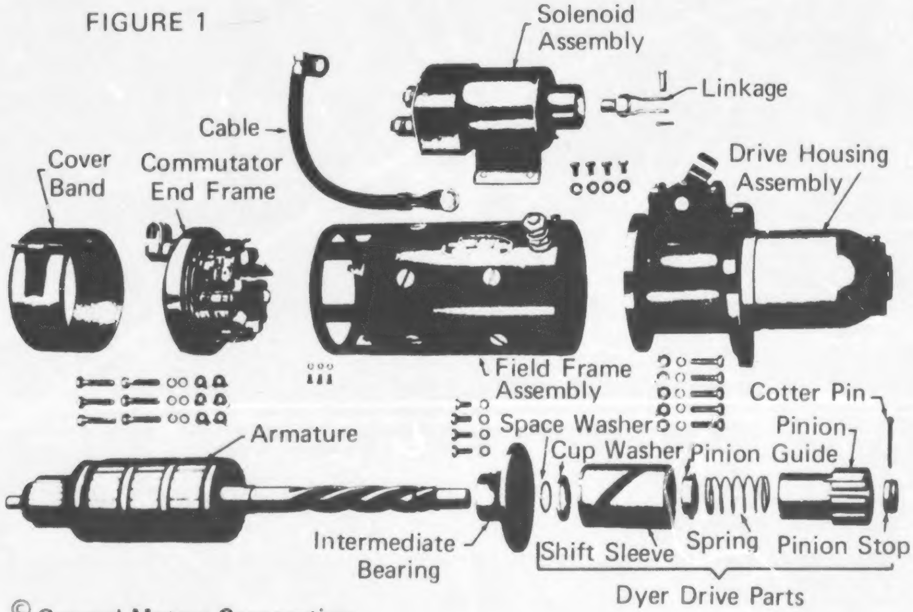
- A. Vehicle
- B. Combination end wrenches, 3/8" - 3/4"
- C. Needle nose pliers
- D. Pliers (two pair)
- E. Hammer
- F. Small wood block
- G. Suitable armature growler and test light
- H. Appropriate service manual

II. Procedure

(CAUTION: Remove all jewelry prior to working on any electrical system and follow all shop safety procedures.)

- A. Disassemble starter (Figure 1)

FIGURE 1


Solenoid Assembly
Linkage
Cable
Cover Band
Commutator End Frame
Drive Housing Assembly
Field Frame Assembly
Cotter Pin
Space Washer
Pinion Guide
Cup Washer
Pinion
Armature
Intermediate Bearing
Shift Sleeve
Spring
Pinion Stop
Dyer Drive Parts

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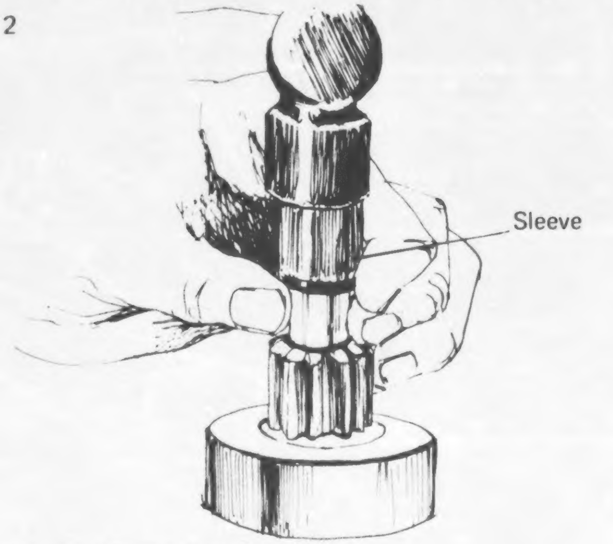
JOB SHEET #2

1. Disconnect field coil connectors from solenoid
2. Remove thru bolts
3. Remove starter end frame
4. Grasp starter housing and remove the armature and drive assembly from the housing
5. Remove the armature and drive assembly from the drive housing

   (NOTE: Sometimes the solenoid and shift lever assembly must be removed before the drive assembly and armature can be removed.)

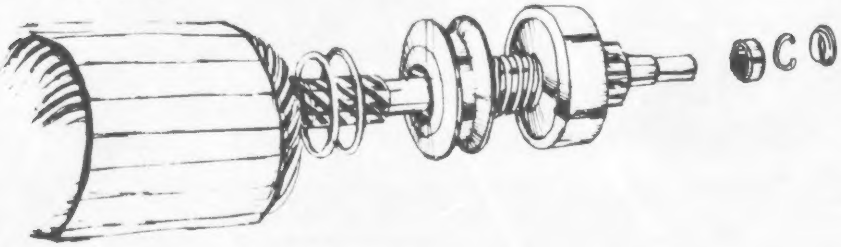
6. Remove starter drive from armature shaft as follows:
   a. Remove thrust washer
   b. Tap retainer toward armature to free the snap ring (Figure 2)

FIGURE 2



   c. Remove snap ring and retainer
   d. Remove starter drive and assist spring (Figure 3)

FIGURE 3



JOB SHEET #2

7. Remove starter brushes, if required

B. Test and service starter

1. Clean all starter components

   (NOTE: Clean all parts by wiping with clean cloths. The armature, field coils, and starter drive assembly must not be washed in solvent.)

2. Arrange all starter components for inspection

3. Inspect starter bushing for looseness and replace as required

4. Inspect starter brushes for wear

   (NOTE: Brushes worn to half their original length or less should be replaced.)

5. Inspect the starter drive

   (NOTE: The starter drive pinion gear should turn freely in one direction and lock when turned slowly in the other direction.)

6. Inspect armature commutator

   (NOTE: If the armature commutator is rough or out-of-round, it should be turned down using suitable equipment.)

7. Test the armature for short circuits (Figure 4)

   (NOTE: Place the armature on a growler and rotate the armature while holding a hacksaw blade over the armature core. If the blade vibrates, the armature is shorted and will require replacement.)

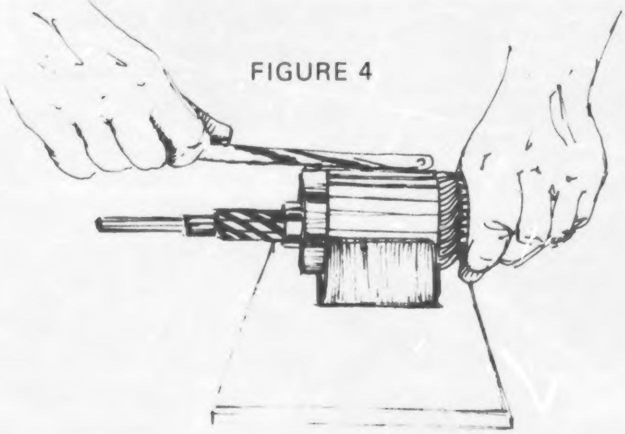


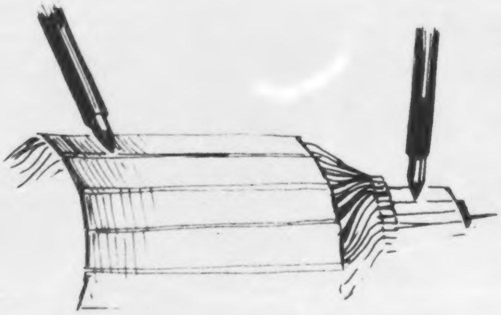
FIGURE 4

JOB SHEET #2

8. Check armature for ground (Figure 5)

(NOTE: Place one lead of a test lamp on the armature core or shaft and the other on the commutator. If the lamp lights, the armature is grounded and will require replacement.)

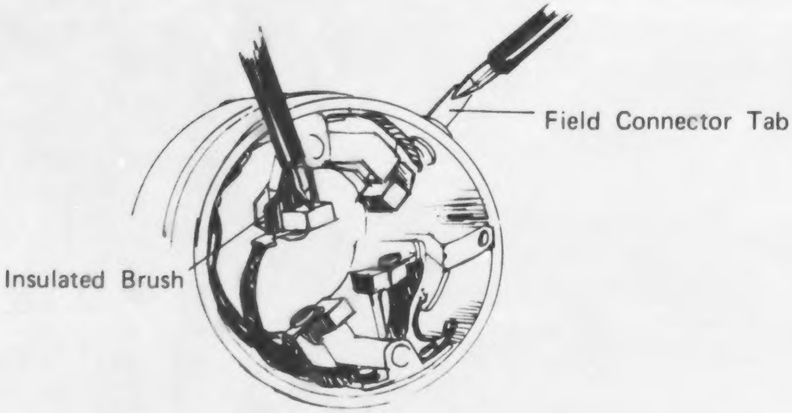
FIGURE 5



9. Check field coil for open circuit (Figure 6)

(NOTE: Place one lead of the test lamp on the insulated brush and the other on the field connection tab. If the lamp does not light, the field coils are open and will require replacement.)

FIGURE 6

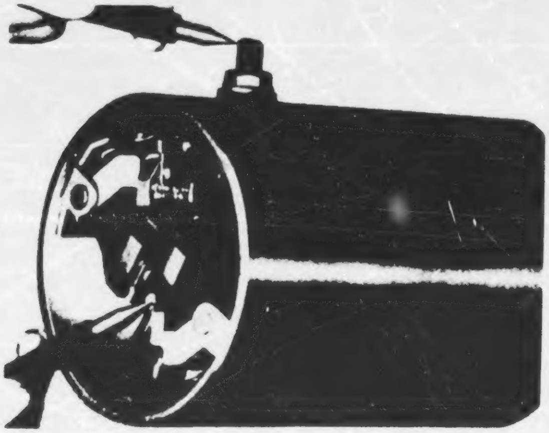


JOB SHEET #2

10. Check field coil for ground (Figure 7)

    (NOTE: Place one lead of the test lamp on the field connector tab and the other on the grounded brush. If the lamp lights, the field coils are grounded and will require replacement.)

    FIGURE 7



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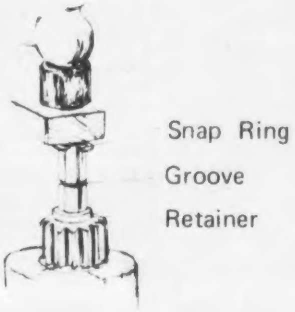
11. Test, inspect, and replace any parts that are worn or damaged before reassembling starter

C. Reassemble starter

1. Assemble and install starter brush rigging, if required
2. Attach wires to starter brush assemblies
3. Install starter drive on armature shaft
4. Drive snap ring on shaft (Figure 8)

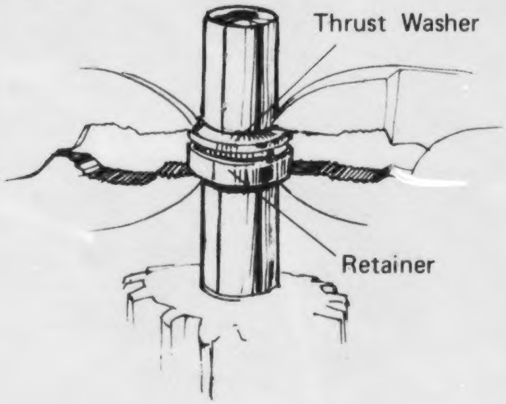
FIGURE 8



JOB SHEET #2

5. Force snap ring into retainer (Figure 9)

FIGURE 9



6. Lubricate drive housing bushing with 4 to 5 drops of light oil

7. Make sure thrust collar is in place against snap ring and retainer

8. Slide armature and starter drive assembly into place in drive housing, engaging shift lever with starter drive as required

   (NOTE: Install solenoid if removed.)

9. Position field frame over armature

   (NOTE: Use care when positioning field frame against drive housing to prevent damage to the brushes.)

10. Place 4 to 5 drops of light oil on starter end frame bushing

11. Place leather brake washer on armature shaft

12. Install starter end frame and start thru bolts

13. Tighten thru bolts evenly and securely

14. Reconnect the field coil connectors to the solenoid

15. Test starter with a battery and jumper cables to determine starter motor performance

STARTING CIRCUITS
UNIT V

JOB SHEET #3--TEST STARTER CIRCUIT (NO-LOAD)

I. Tools and materials

- A. Engine
- B. Basic hand tool set
- C. Fully charged battery
- D. Ammeter
- E. Starter technical manual specifications
- F. Voltmeter
- G. Carbonpile resistor
- H. Tachometer
- I. Safety glasses
- J. Appropriate service manual

II. Procedures

(CAUTION: Remove all jewelry prior to working on any electrical system and follow all shop safety procedures.)

A. Inspect starter motor before removal

1. Engage starting motor drive gear and listen for clashing teeth
2. Release motor drive from flywheel and listen for squealing or rattling noise

   (NOTE: 1 and 2 above indicate a dry or worn drive mechanism.)

3. Look for loose mounting bolts
4. Remove commutator end frame and check for burned commutator bars, high mica, worn brushes, or an oily commutator and brushes

   (NOTE: Correct 3 and 4 before further testing, if necessary.)

5. Check pinion gear for freedom of movement by turning shaft

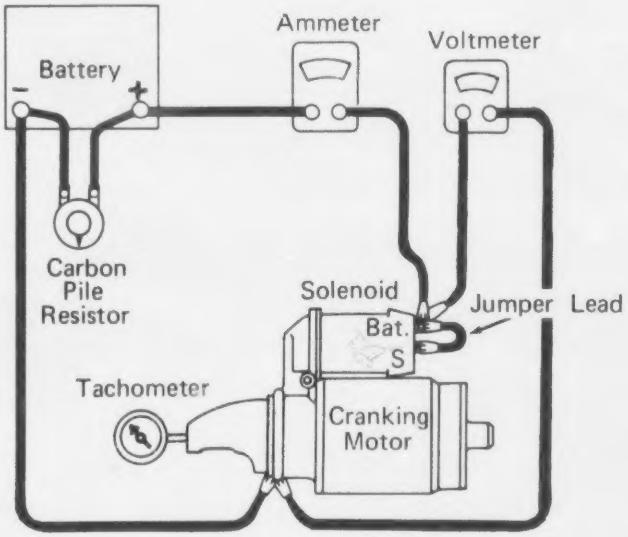
B. Conduct no-load test

1. Remove starter from engine

JOB SHEET #3

2. Connect starter motor to a fully charged battery (Figure 1)

FIGURE 1


Battery
−
+
Ammeter
Voltmeter
Carbon Pile Resistor
Solenoid
Bat.
S
Jumper Lead
Tachometer
Cranking Motor

3. Connect an ammeter between battery and starting motor (Figure 1)

4. Connect a jumper wire between the "s" terminal and the battery post so solenoid current draw is not measured, if technical manual specification is for basic motor only (Figure 1)

5. Connect voltmeter to starting motor terminal and frame (Figure 1)

6. Connect carbon pile resistor across the battery (Figure 1)

7. Place a tachometer on end of armature to measure armature speed (Figure 1)

8. Start motor by connecting leads to battery terminal

9. Vary the carbon pile resistor until the specified voltage is shown on the voltmeter

10. Read the ammeter for the current draw

11. Read the tachometer for the armature speed

12. Compare the readings with the technical manual specifications for the starter motor being tested

JOB SHEET #3

C. Interpret no-load test results

1. Rated current draw and no-load speed indicates a normal starter motor condition
2. Low free speed and high current draw indicate:
    a. Too much friction
    b. Shorted armature
    c. Grounded armature of fields
3. Failure to operate with high current draw indicates:
    [illegible]. A direct ground in the terminal or fields
    b. Frozen bearings
4. Failure to operate with no current draw indicates:
    a. Open field circuit
    b. Open armature coils
    c. Broken brush springs, worn brushes, or high insulation between commutator bars
5. Low speed and low current draw indicates high internal resistance due to poor connections, dirty commutator, or an open field circuit
6. High free speed and high current draw indicate shorted fields

STARTING CIRCUITS
UNIT V

JOB SHEET #4--RECONDITION STARTING MOTOR ARMATURE

I. Tools and materials

- A. Starting motor
- B. Basic hand tool set
- C. Special tool for turning commutators or a lathe
- D. Special tool for undercutting commutator or hacksaw blade
- E. Safety glasses
- F. Appropriate service manual

II. Procedure

(CAUTION: Remove all jewelry prior to working on any electrical system and follow all shop safety procedures.)

A. Turn down commutator

1. Secure armature and special tool in vise or lathe (Figure 1)

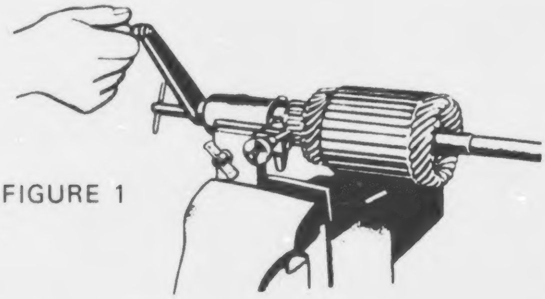


FIGURE 1

2. Remove only enough metal to "true-up" the commutator

B. Undercut the mica between commutator bars

1. Secure armature and special tool in vise (Figure 1)

(NOTE: Use hacksaw blade saw with same width as distance between commutator bars if special tool is not available.)

JOB SHEET #4

2. Undercut mica on commutator

   (NOTE: Always consult starting motor specifications before reconditioning armature. Most high output starting motor armatures should not be undercut after the armature is turned down.)

STARTING CIRCUITS
UNIT V

JOB SHEET #5--CHECK VOLTAGE DROP IN A STARTER CIRCUIT

I. Tools and materials

- A. Engine
- B. Voltmeter
- C. Appropriate service manual

II. Procedure

(CAUTION: Remove all jewelry prior to working on any electrical system and follow all shop safety procedures.)

- A. Connect voltmeter positive lead to positive battery (+) terminal
- B. Connect negative voltmeter lead to large cable connector on starter solenoid
- C. Set voltmeter on lowest scale reading or about 4 volts
- D. Crank engine and watch meter

  (CAUTION: Prevent engine from starting.)
- E. Check total voltage drop; it should not be over 0.5 volts for a 12-volt system

STARTING CIRCUITS
UNIT V

NAME ______________________________

TEST

1. Match the terms on the right with their correct definitions.

_____a. Ends of a magnet in the field frame assembly of a starting motor

_____b. Wire wrapped around pole pieces to increase the strength of the magnetic field when current is passed through the windings

_____c. Main drive of starter motor; converts electrical energy into mechanical energy

_____d. Metal segments attached to ends of wire loops to form contact surface on armature

_____e. Sliding contacts to feed electrical energy from battery to commutator

_____f. Small gear that meshes with a larger gear

_____g. Electromagnetic switch that closes circuit and engages the motor drive pinion with the flywheel

_____h. Manual, magnetic, or solenoid switch

_____i. Tendency of a body in motion to remain in motion

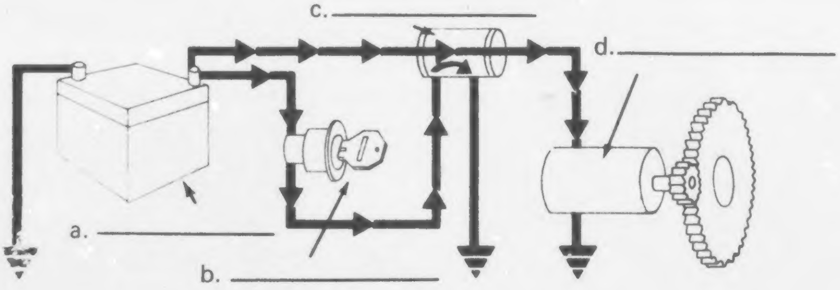
_____j. Counter electromotive force

1. Armature
2. Solenoid
3. Pinion
4. Pole pieces
5. Field winding
6. Commutator
7. Brushes
8. Inertia
9. Motor switch
10. Cemf

2. Explain the purpose of a starting circuit.

____

3. Label the major parts in a starting circuit.



4. Match the major parts of a starting circuit on the right with their correct functions.

______ a. Supplies energy for the circuit

______ b. Activates the circuit

______ c. Closes circuit to motor and engages motor drive with flywheel

______ d. Drives flywheel to start engine

1. Motor switch
2. Starter switch
3. Starting motor
4. Battery

5. Name four major parts of a starting motor.

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

6. Match the component parts of a starting motor on the right with their correct functions.

______ a. Forms a magnetic field of force around armature

______ b. Wrapped around pole shoe to strengthen magnetic field when current is passed through the winding

______ c. Converts electrical energy into mechanical energy to drive mechanism to crank engine

______ d. Forms contact surface for battery to feed electrical current through armature

______ e. Sliding contacts which feed electrical energy to the commutator

1. Armature
2. Field winding
3. Commutator
4. Brushes
5. Pole shoe

7. Explain how a basic starting motor converts electrical energy into mechanical energy.

____

____

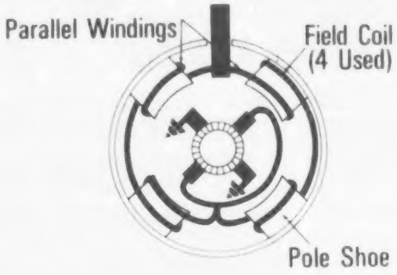
8. Select true statements concerning how a starting motor is kept running by placing an "X" in the appropriate blanks.

______ a. The magnetic field around the armature and the magnetic field between the pole pieces repel each other causing the armature to turn

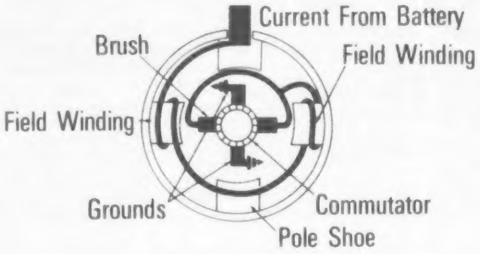
______ b. Metal segments on the ends of the commutator make a one-half turn reversing their connection through sliding contacts which causes the current to flow in the opposite direction in the armature windings

9. Discuss the current f[illegible]rting motor circuit.

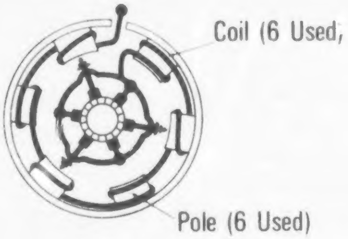
10. Identify four types of starter field circuits.


Parallel Windings
Field Coil (4 Used)
Pole Shoe

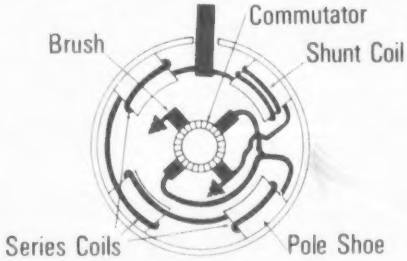
a. ______


Current From Battery
Brush
Field Winding
Field Winding
Grounds
Commutator
Pole Shoe

b. ______


Coil (6 Used,
Pole (6 Used)

c. ______


Commutator
Brush
Shunt Coil
Series Coils
Pole Shoe

d. ______

11. Match the types of starter field circuits on the right with the current flow in each type circuit.

______a. Current flows through all the field windings before it flows through the two insulated brushes to the armature

______b. Current flows through one field winding to the brushes, and also through the other field winding to the brushes, placing the field windings in parallel

______c. One-third of the current flows through each pair of field windings to one of the three insulated brushes

______d. One or more of the poles is shunt wound, connected directly to ground to prevent excessive speeds

1. Compound-wound
2. Series-wound
3. Series-parallel-wound
4. Parallel-wound

12. Select true statements concerning counter electromotive force in relation to armature speed by placing an "X" in the appropriate blanks.

______a. Counter voltage is induced into the armature windings when they pass through the magnetic field of the field coils

______b. The faster the armature turns the lower the counter voltage

______c. The compound-wound starter shunt winding prevents excessive speeding because the shunt winding is connected directly to ground, reducing the series field winding, armature current flow, and armature free speed

13. Name four types of switches for starting motors.

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

14. Distinguish between a magnetic switch and a solenoid switch by placing an "X" next to the description of the magnetic switch.

______a. Provides a mechanical means of shifting pinion into mesh with flywheel

______b. Normally used with bendix drive as switch does not provide mechanical shifting of drive mechanism

15. Arrange in order the steps in the operation of a series-parallel switch by placing the correct sequence number in the appropriate blank.

______a. Solenoid circuit is completed by a set of points mechanically closed by the series-parallel switch plunger and starter turns over

______b. Starter switch closes, connecting two 12 volt batteries in series with the starting motor

______c. Starter switch is released, going into neutral position, permitting operation of electrical equipment by two 12 volt batteries in parallel for normal operation

16. Explain two ways starter drives are engaged.

a. ______________________________

b. ______________________________

17. List three types of electromagnetic or lever shift drives.

    a. ______________________________

    b. ______________________________

    c. ______________________________

18. Demonstrate the ability to:

    a. Remove and replace a starter.

    b. Disassemble, test, and reassemble a starter.

    c. Test starter circuit (no-load).

    d. Recondition starting motor armature.

    e. Check voltage drop in a starter circuit.

    (NOTE: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

STARTING CIRCUITS
UNIT V

ANSWERS TO TEST

1. a. 4
   b. 5
   c. 1
   d. 6
   e. 7
   f. 3
   g. 2
   h. 9
   i. 8
   j. 10

2. Explanation should include--Converts electrical energy from the battery into mechanical energy at the starting motor to crank the engine

3. a. Battery
   b. Starter switch
   c. Motor switch
   d. Starting motor

4. a. 4
   b. 2
   c. 1
   d. 3

5. a. Motor switch
   b. Field frame assembly
   c. Armature
   d. Drive mechanism

6. a. 5
   b. 2
   c. 1
   d. 3
   e. 4

7. Explanation should include--Current carrying conductor (armature) formed in a loop and mounted on a shaft, will cause the shaft to rotate when placed inside a magnetic field (field windings)

8. a, b

9. Discussion should include--Current will flow from battery, through cable, across switch contacts, through field windings and armature, and back to battery through ground

10. a. Parallel-wound
    b. Series-wound
    c. Series-parallel-wound
    d. Compound-wound

11. a. 2
    b. 4
    c. 3
    d. 1

12. a, c

13. a. Manual
    b. Solenoid
    c. Magnetic
    d. Series-parallel

14. b

15. a. 2
    b. 1
    c. 3

16. Explanation should include:

    a. Inertia of armature acting through drive mechanism
    b. Electromagnetic plunger to mechanically shift pinion into mesh

17. a. Overrunning clutch
    b. Dyer drive
    c. Sprag clutch drive

18. Performance skills evaluated to the satisfaction of the instructor

IGNITION CIRCUITS
UNIT VI

UNIT OBJECTIVE

After completion of this unit, the student should be able to remove and install a distributor, replace contact points and condenser, and check and set ignition timing. The student should also be able to remove, service, and replace spark plugs. This knowledge will be evidenced by correctly performing the procedures outlined in the job sheets and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to ignition circuits with their correct definitions.
2. Explain the purpose of an ignition circuit.
3. Identify the components of an ignition circuit.
4. Match the components of an ignition circuit with their correct functions.
5. Distinguish between primary and secondary ignition circuit components.
6. Identify the components of a distributor.
7. Arrange in order the steps in the operation of an ignition circuit beginning with the battery through one complete cycle.
8. Distinguish between transistorized and capacitive discharge ignition systems.
9. Identify the major components of an electronic ignition system.
10. Match the major components of an electronic ignition system with their functions.
11. Demonstrate the ability to:
    a. Remove and install a distributor.
    b. Remove and replace contact points and condenser.
    c. Adjust dwell on an externally adjustable distributor.
    d. Check and set ignition timing.
    e. Remove, service, and replace spark plugs.

IGNITION CIRCUITS
UNIT VI

SUGGESTED ACTIVITIES

I. Provide student with objective sheet.

II. Provide student with information and job sheets.

III. Make transparencies.

IV. Discuss unit and specific objectives.

V. Discuss information sheet.

VI. Demonstrate and discuss the procedures outlined in the job sheets.

VII. Discuss spark plug heat range.

VIII. Discuss the different methods of ignition bypass.

IX. Show electronic parts to students and explain their operation.

X. Have Champion Spark Plug Mobile Unit visit class.

XI. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

  A. Objective sheet

  B. Information sheet

  C. Transparency masters

    1. TM 1--Components of an Ignition Circuit

    2. TM 2--Primary Circuit

    3. TM 3--Secondary Circuit

    4. TM 4--Distributor Components

    5. TM 5--Operation of an Ignition Circuit - A

    6. TM 6--Operation of an Ignition Circuit - B

    7. TM 7--Operation of an Ignition Circuit - C

8. TM 8--Operation of an Ignition Circuit - D

9. TM 9--Operation of an Ignition Circuit - E

10. TM 10--Major Components of an Electronic Ignition System

D. Job sheets

1. Job Sheet #1--Remove and Install a Distributor

2. Job Sheet #2--Remove and Replace Contact Points and Condenser

3. Job Sheet #3--Adjust Dwell on an Externally Adjustable Distributor

4. Job Sheet #4--Check and Set Ignition Timing

5. Job Sheet #5--Remove, Service, and Replace Spark Plugs

E. Test

F. Answers to test

II. References:

A. *Fundamentals of Service: Electrical Systems*. Fourth Edition. Moline, IL: Deere and Company, 1979.

B. Billiet, Walter E., and Goings, Leslie F. *Automotive Electrical Systems*. Third Edition. Chicago: American Technical Society, 1970.

C. Crouse, William H. *Automotive Mechanics*. New York: Webster Division/ McGraw-Hill Book Company, 1975.

D. Dagel, John F. *Diesel Engine Repair*. New York: John Wiley and Sons, Inc., 1982.

E. Foutes, William A. *Diesel Engine Mechanics*. Stillwater, OK: Mid-America Vocational Curriculum Consortium, 1977.

IGNITION CIRCUITS
UNIT VI

INFORMATION SHEET

I. Terms and definitions

   A. Timing--Igniting the fuel-air mixture at the exact instant that will enable the engine to develop maximum power

   B. Timing marks--Marks used to synchronize the ignition circuit so that plugs will fire at the precise time

      (NOTE: Timing marks are usually located on the vibration damper or flywheel.)

   C. Primary ignition circuit--Low voltage circuit which energizes the ignition coil

   D. Secondary ignition circuit--High voltage circuit which produces electrical current to jump spark plug gap

   E. Dwell--Number of degrees of distributor cam rotation that the ignition points are closed

   F. Condenser--A unit installed between the breaker points and coil to prevent arcing

      (NOTE: A condenser has the ability to absorb and retain surges of electricity.)

   G. Coil polarity--A means of connecting the coil primary windings to the distributor so that current produced at the spark plug will travel from center electrode to ground

      Example: On negative-ground systems, the negative primary terminal of coil is connected to the distributor. On positive-ground systems, the positive primary terminal is connected to the distributor

   H. Electronic ignition system--Ignition system using a control unit and magnetic pickup to open and close the primary circuit

   I. Electronic module--A switching device that opens and closes the ignition to primary ground circuit

   J. Stator--Rotating part in distributor that breaks the magnetic field in the pickup coil

II. Purpose of an ignition circuit--The ignition circuit produces a high voltage spark which ignites the fuel-air mixture in the engine cylinder

INFORMATION SHEET

III. Components of an ignition circuit (Transparency 1)

A. Battery

B. Ignition switch

C. Primary resistance unit

D. Ignition coil

E. Contact points

F. Condenser

G. Distributor

H. Breaker cam

I. Spark-advance mechanism

(NOTE: There are two types of spark-advance mechanisms, vacuum and mechanical. Engine vacuum controls timing advance in relation to engine load. Mechanical advance changes engine timing according to engine speed.)

J. Rotor

K. Distributor cap

L. Spark plug

M. Primary ignition wire

N. Secondary ignition cable

O. Ignition bypass circuit

IV. Components of an ignition circuit and their functions (Transparency 1)

A. Battery--Source of electrical power

B. Ignition switch--Opens and closes the primary circuit between battery and contact points

C. Primary resistance unit–Reduces voltage in the primary circuit to protect the contact points

D. Ignition coil--Transforms low voltage into high voltage necessary to jump the spark plug gap

E. Contact points--Make and break the primary circuit to allow the coil to produce high voltage at the spark plugs

F. Condenser--Device that aborbs surges in the primary circuit when the opening of the ignition points causes an interruption in current flow

INFORMATION SHEET

G. Distributor--Contains the contact points and condenser; distributes the high voltage current from the coil to the proper cylinder

H. Breaker cam--Opens and closes the contact points

I. Spark-advance mechanism--Regulates the timing of the high voltage circuit for best ignition during all speed and load conditions

J. Rotor--Takes the high voltage current from the coil and directs it to the correct cylinder

K. Distributor cap--Holds the coil and spark plug wires in a sequence and provides a cover for the distributor

L. Spark plug--Provides a spark gap inside the engine cylinder to ignite the fuel-air mixture

M. Primary ignition wire--Carries low voltage from the battery to the primary side of the ignition coil (light wire)

N. Secondary ignition cable--Carries high voltage from the secondary side of the coil to the spark plug (heavily insulated wire)

O. Ignition bypass circuit--Primary ignition circuit that bypasses the ignition resistance unit, permitting full battery voltage to the ignition coil during starting only

V. Ignition circuit components

A. Primary--Low voltage circuit (Transparency 2)

1. Battery
2. Ignition switch
3. Resistance unit
4. Primary winding of the coil
5. Contact points
6. Condenser
7. Low voltage wire that connects the units

B. Secondary--High voltage circuit (Transparency 3)

1. Secondary winding of the coil
2. Distributor cap
3. Rotor

INFORMATION SHEET

4. Spark plug

5. High voltage wire that connects the units

VI. Distributor components (Transparency 4)

   A. Distributor cap

   B. Rotor

   C. Centrifugal advance mechanism

   D. Condenser

   E. Vacuum advance unit

   F. Breaker plate

   G. Distributor cam

   H. Contact points

   I. Distributor housing

   J. Primary lead wire

   K. Distributor drive gear

VII. Operation of an ignition circuit

   A. With the ignition switch on and the contact points closed, low voltage current flows from the battery through the primary winding of the coil and through the contact points to ground (Transparency 5)

   B. The flow of low voltage current through the primary windings of the coil causes a magnetic field buildup (Transparency 6)

   C. As the contact points open, current attempts to flow across the point surfaces; the condenser attached to the points absorbs this flow of current (Transparency 7)

   D. Stopping this flow of current causes the magnetic field of the coil to collapse across the secondary coil windings, causing a high voltage surge (Transparency 8)

   E. This high voltage surge is directed from the secondary windings of the coil through the distributor cap and rotor and on to the spark plug to ground (Transparency 9)

INFORMATION SHEET

VIII. Transistorized and capacitive discharge ignition systems

(NOTE: Both variations are designed to increase primary voltage to coil and reduce voltage to points or eliminate points.)

A. Transistorized ignitions

1. Amplifier included in circuit between points and ignition coil
2. Transistors allow very low voltage through the points and very high voltage to the primary windings in coil

B. Capacitive discharge system

1. System contains special ignition distributor, amplifier, and special coil
2. System operates to charge a capacitor to a high voltage which, on signal from distributor, is then discharged through the primary windings in coil

IX. Major components of an electronic ignition system (Transparency 10)

A. Dual ballast resistor

(NOTE: This component is not used on all models.)

B. Control unit

C. Magnetic pickup assembly

D. Armature or reluctor

X. Major components of an electronic ignition system and their functions

A. Dual ballast resistor--Maintains constant primary current with variations in engine speed

(NOTE: The dual ballast resistor is bypassed during engine starting.)

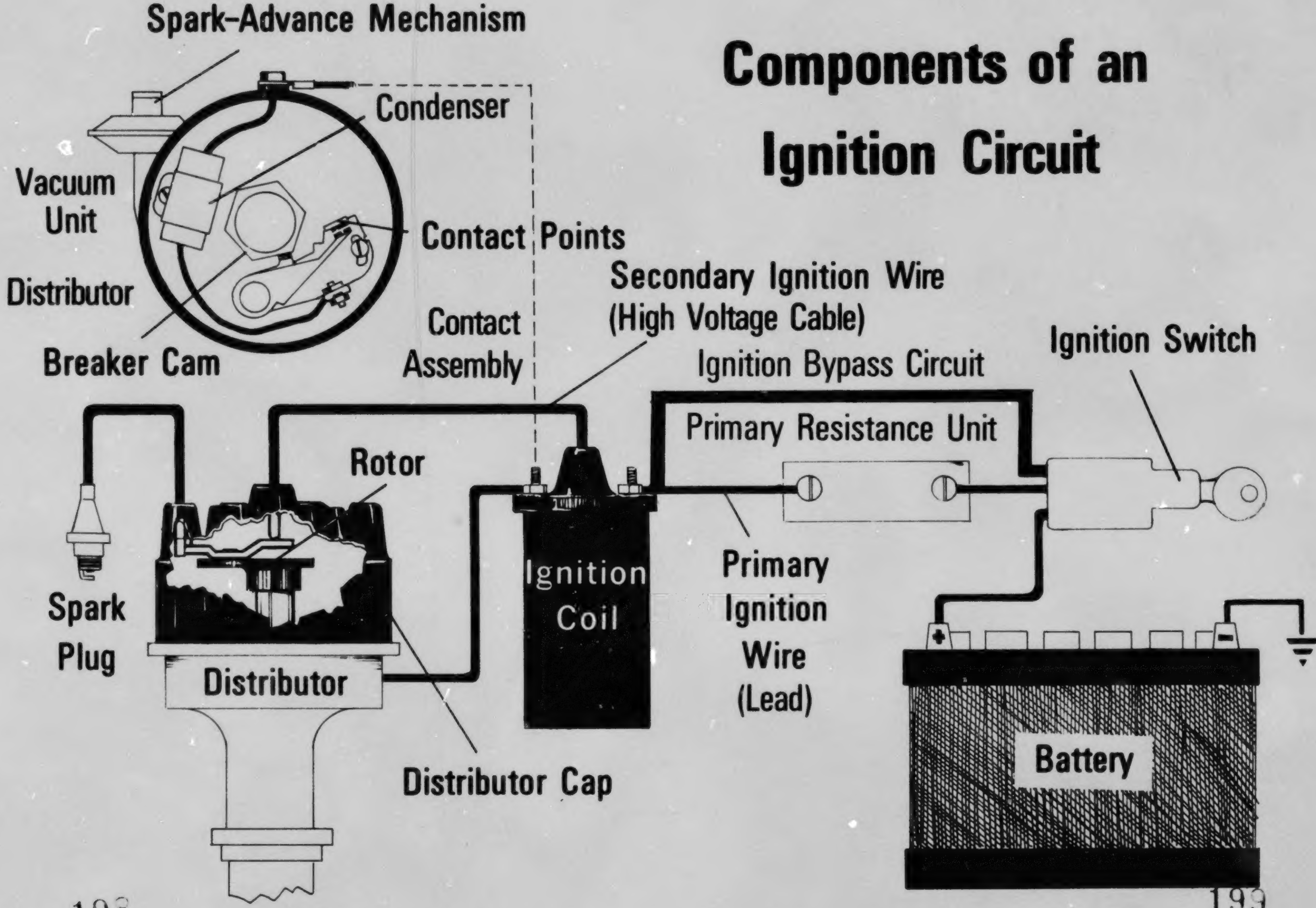
B. Magnetic pickup assembly--Sends a small voltage pulse to the control unit to trigger switching transistor to stop current flow in the coil primary windings

C. Armature or reluctor--Rotates with the distributor shaft, producing a voltage pulse in the magnetic pickup

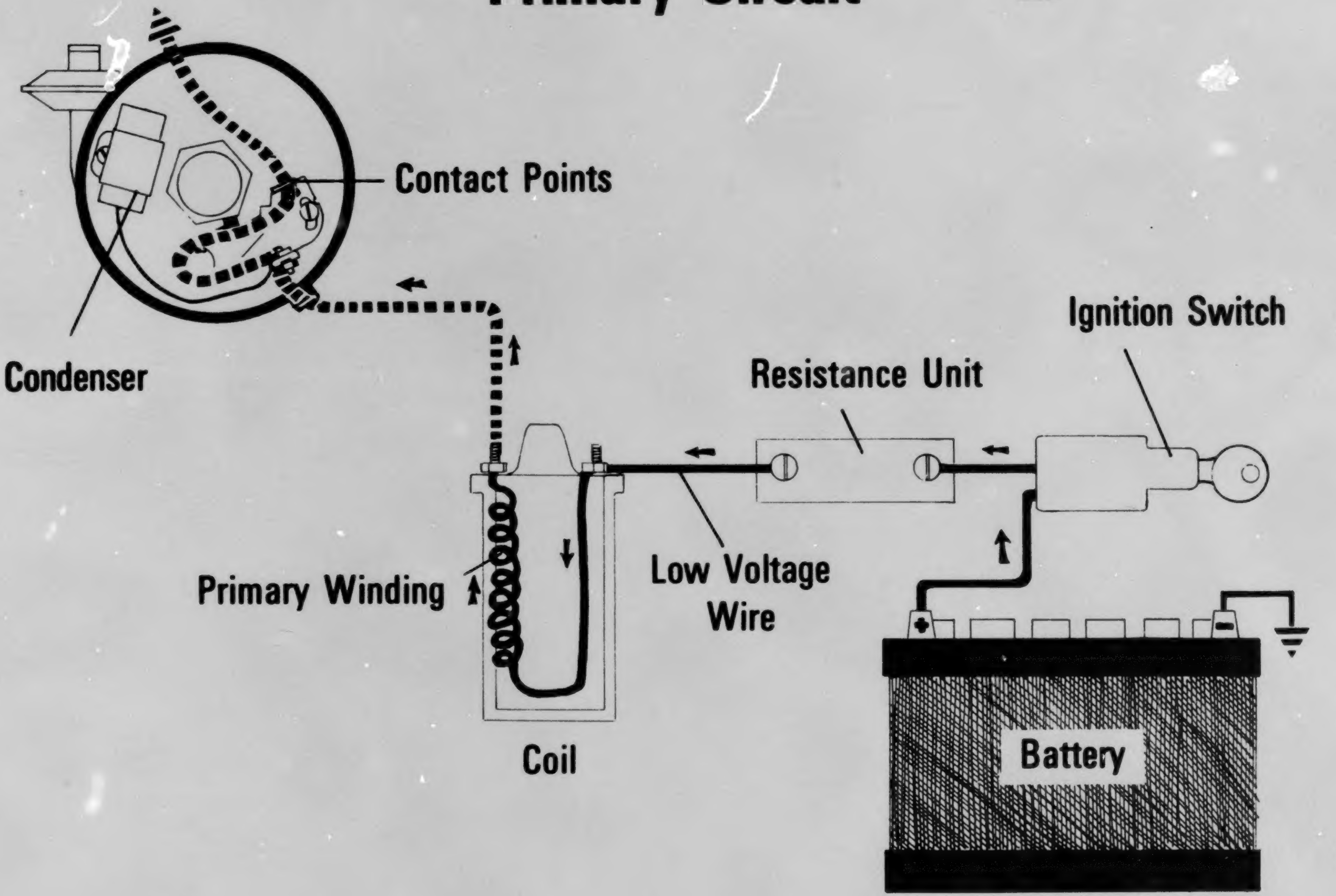
(NOTE: The armature contains the same number of tips as the engine contains cylinders.)

D. Control unit--Controls the flow of current in the primary windings of the ignition coil and maintains constant dwell

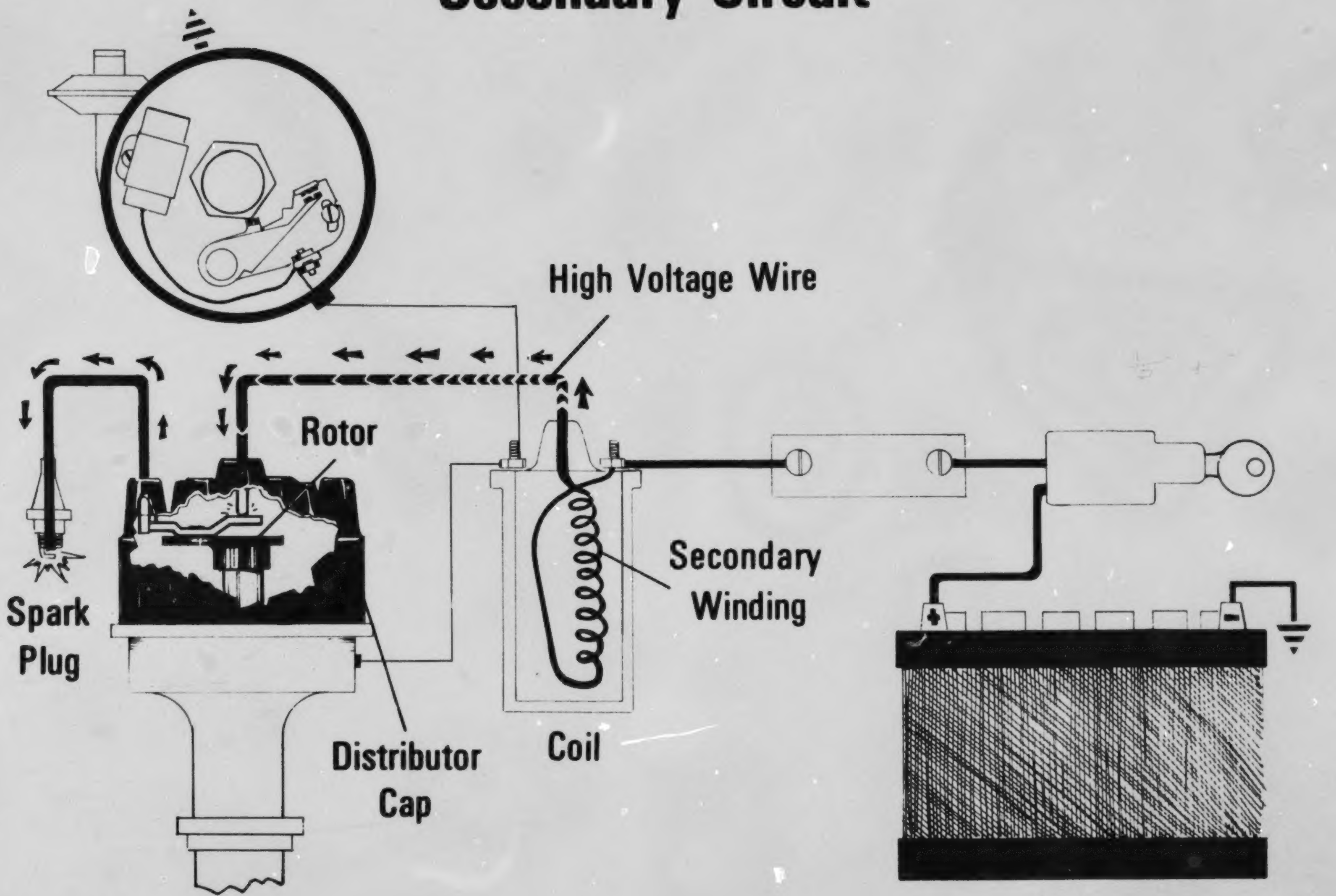
Components of an Ignition Circuit


Spark-Advance Mechanism
Condenser
Vacuum Unit
Contact Points
Distributor
Contact Assembly
Breaker Cam
Secondary Ignition Wire (High Voltage Cable)
Ignition Switch
Ignition Bypass Circuit
Primary Resistance Unit
Rotor
Ignition Coil
Primary Ignition Wire (Lead)
Spark Plug
Distributor
Distributor Cap
Battery
+
−

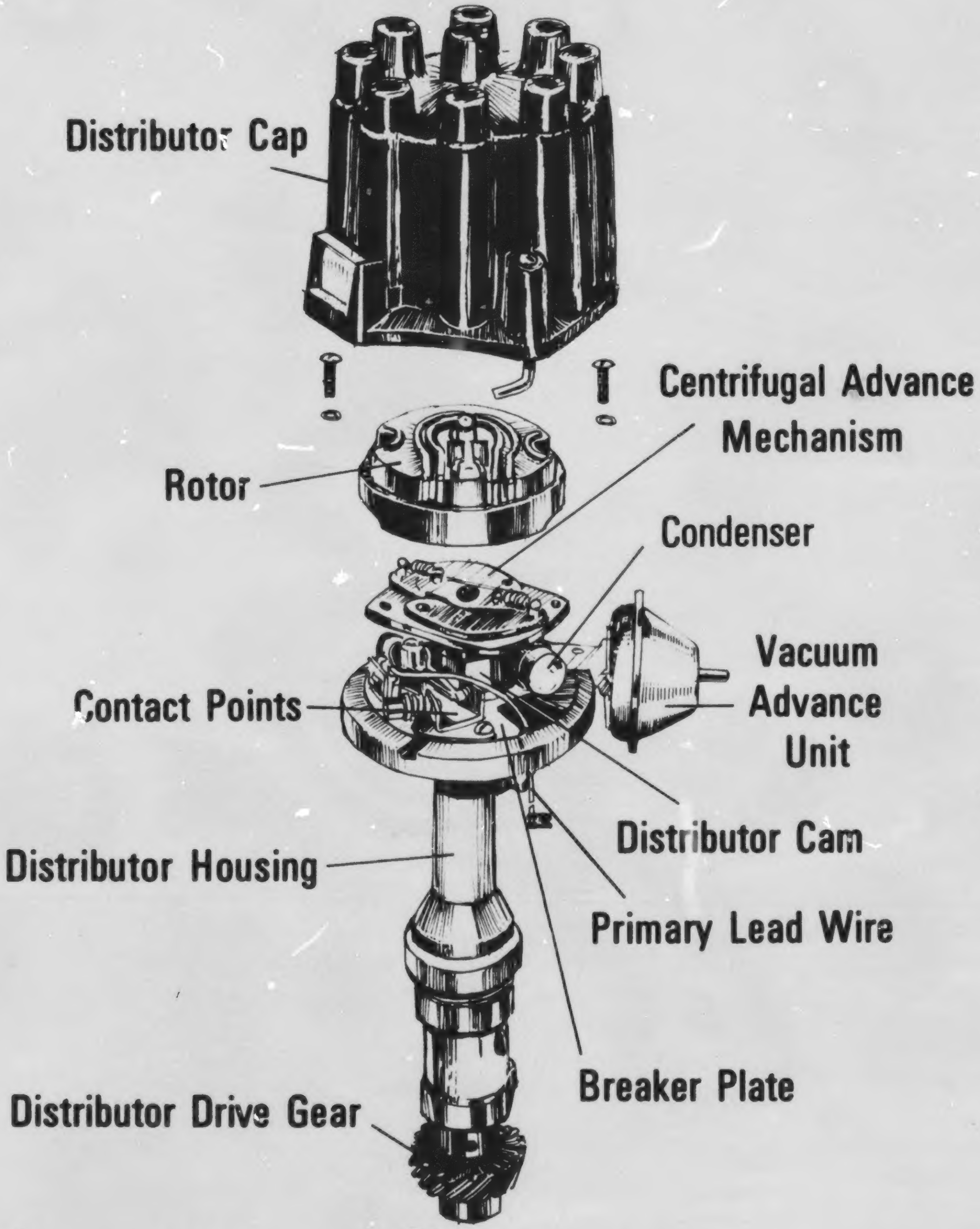
Primary Circuit


Contact Points
Condenser
Ignition Switch
Resistance Unit
Primary Winding
Low Voltage Wire
Coil
Battery
+
-

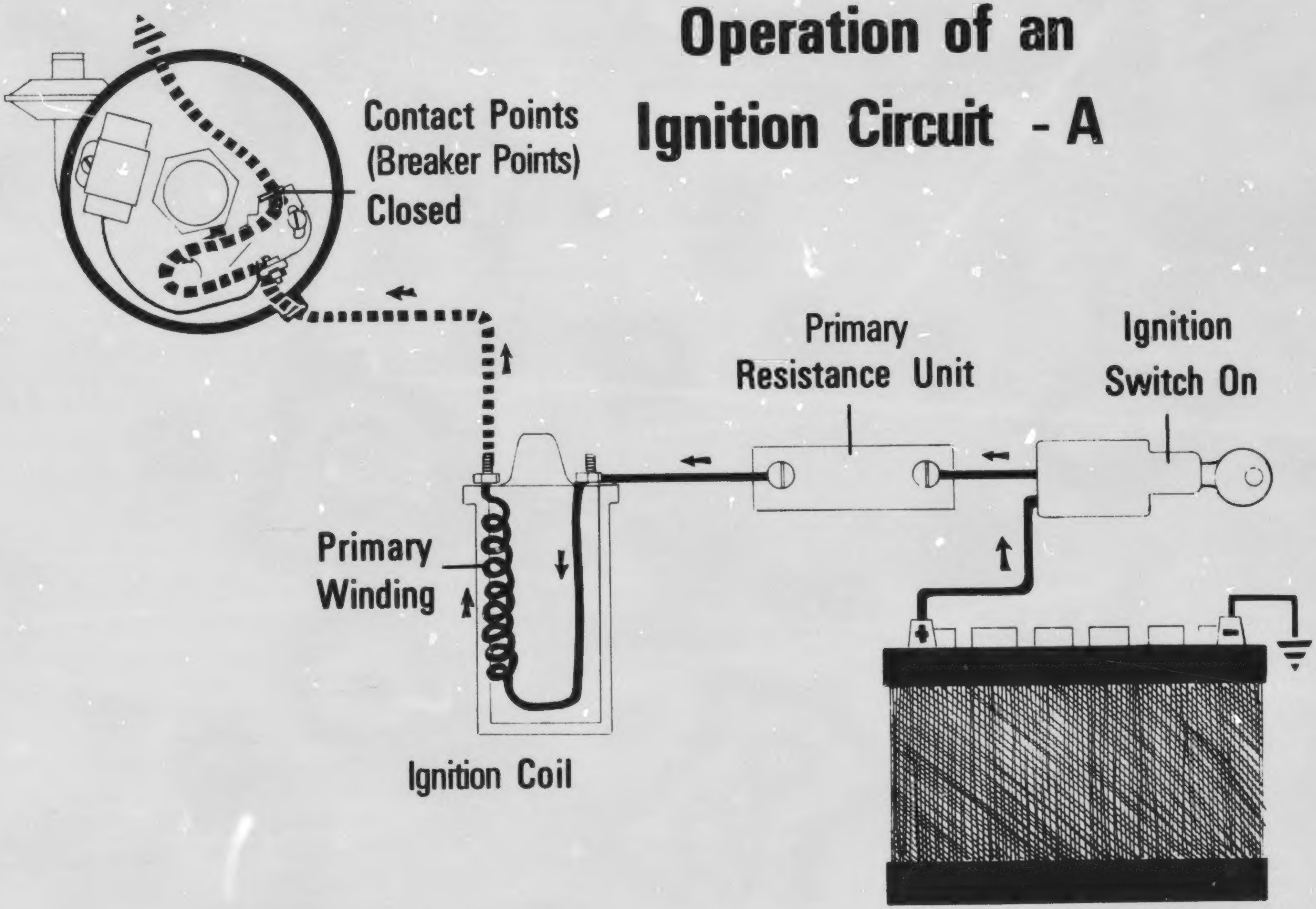
Secondary Circuit


High Voltage Wire
Rotor
Spark Plug
Secondary Winding
Distributor Cap
Coil

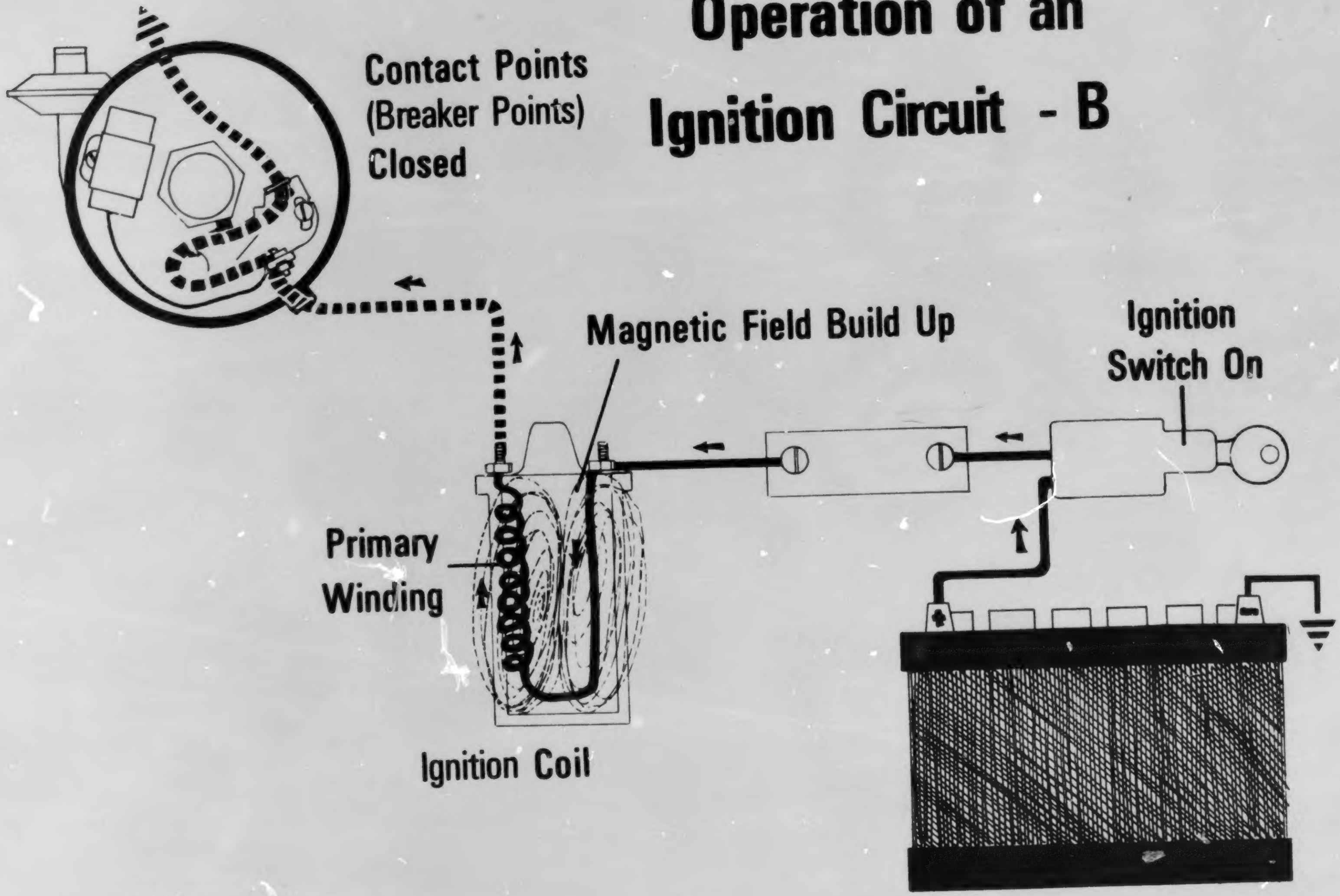
Distributor Components


Distributor Cap
Centrifugal Advance Mechanism
Rotor
Condenser
Vacuum Advance Unit
Contact Points
Distributor Cam
Distributor Housing
Primary Lead Wire
Breaker Plate
Distributor Drive Gear

Operation of an Ignition Circuit - A


Contact Points
(Breaker Points)
Closed
Primary Resistance Unit
Ignition Switch On
Primary Winding
Ignition Coil
+
-

Operation of an Ignition Circuit - B



Contact Points (Breaker Points) Closed

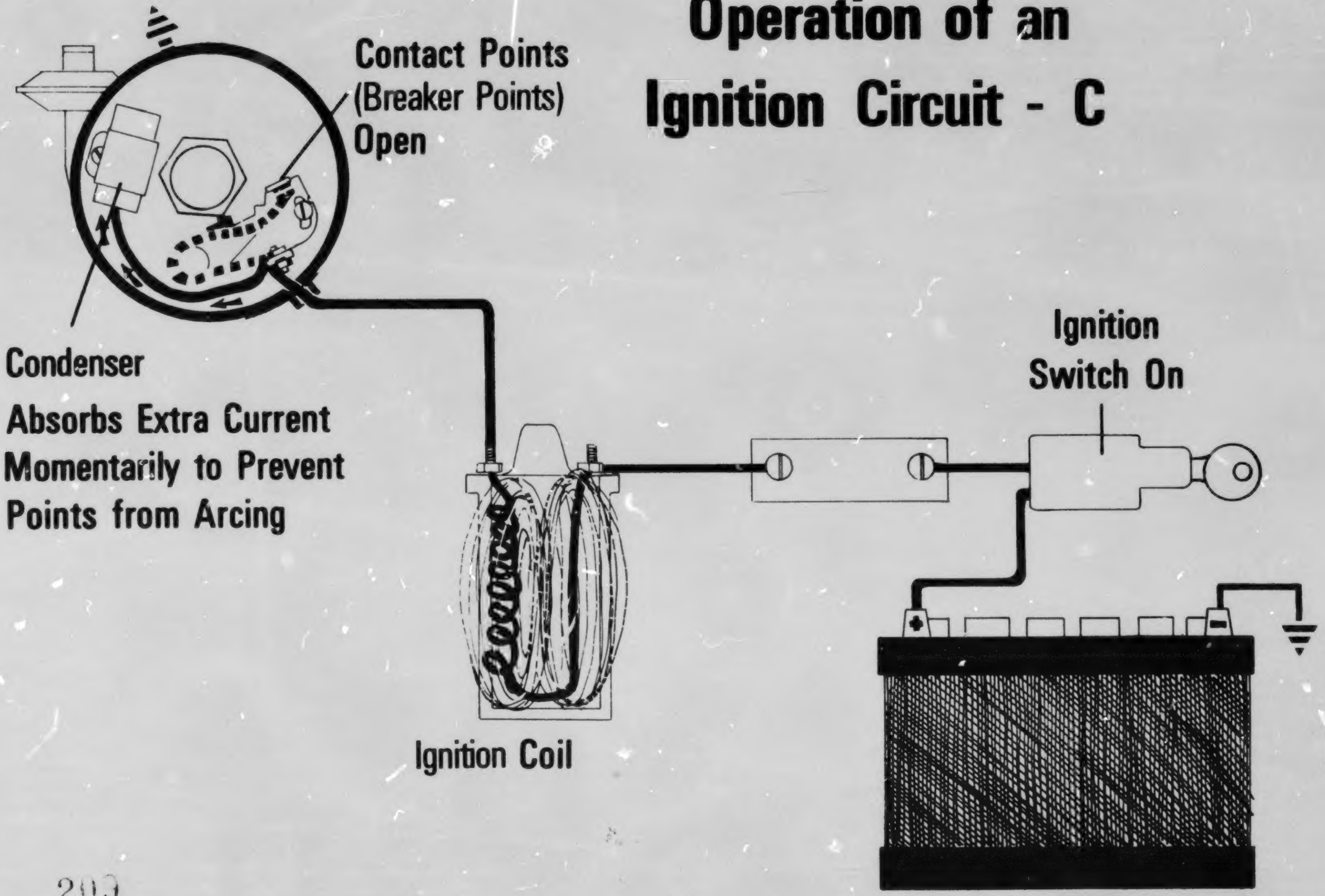
Magnetic Field Build Up

Ignition Switch On

Primary Winding

Ignition Coil

Operation of an Ignition Circuit - C



Contact Points (Breaker Points) Open

Condenser

Absorbs Extra Current Momentarily to Prevent Points from Arcing

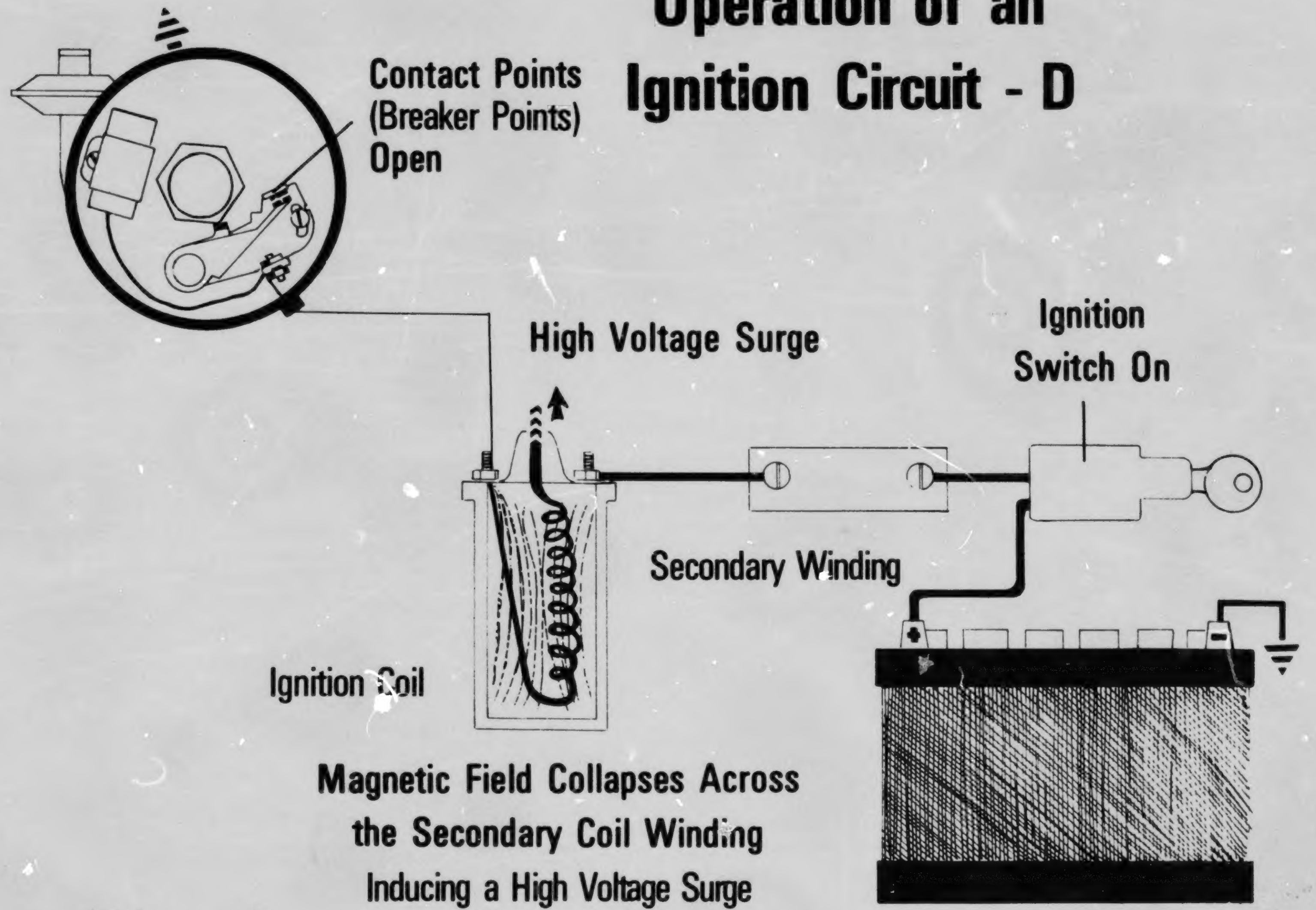
Ignition Switch On

Ignition Coil

TM 7

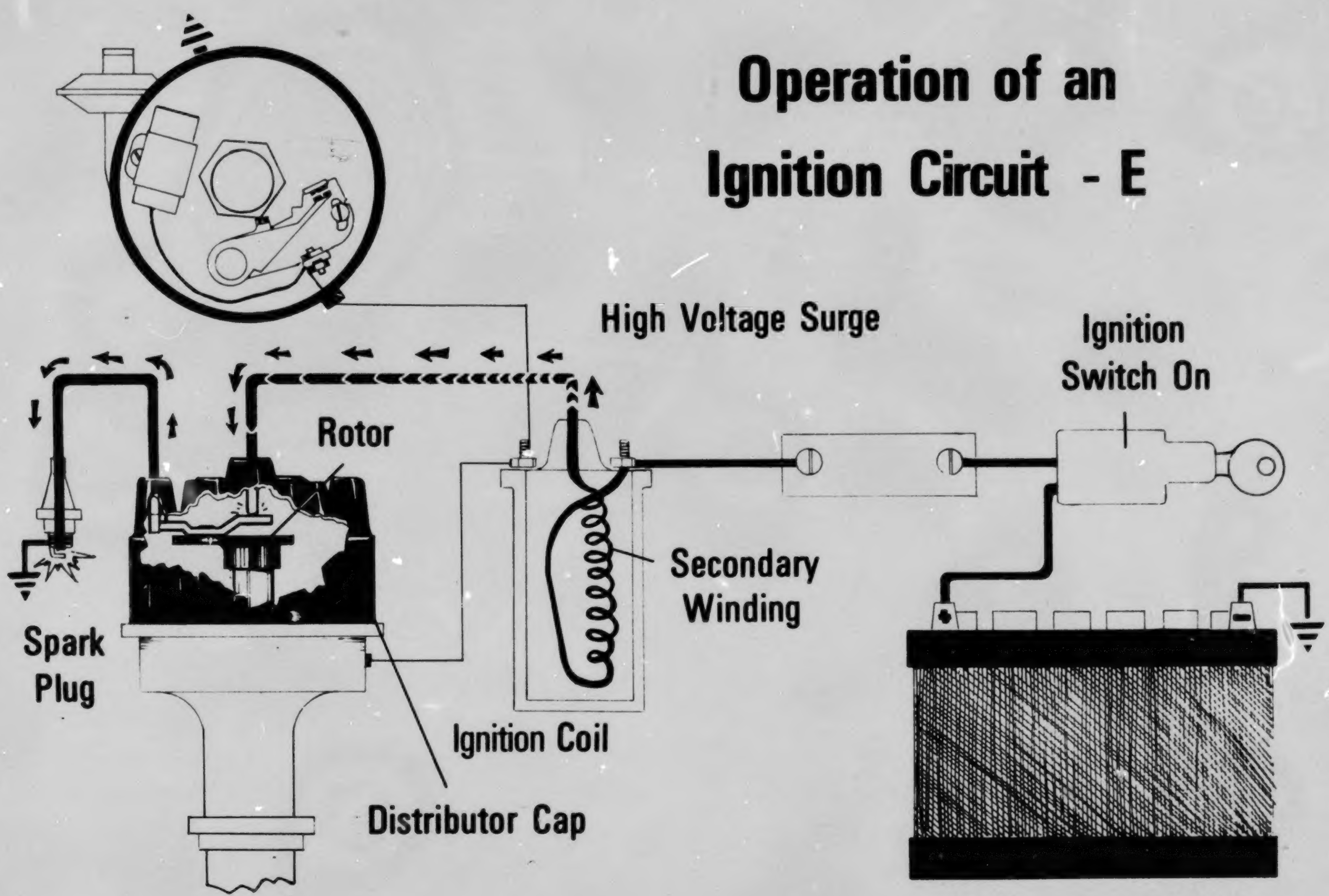
D: ES-215

Operation of an Ignition Circuit - D


Contact Points
(Breaker Points)
Open
High Voltage Surge
Ignition
Switch On
Secondary Winding
Ignition Coil

Magnetic Field Collapses Across the Secondary Coil Winding Inducing a High Voltage Surge

Operation of an Ignition Circuit - E



High Voltage Surge

Ignition Switch On

Rotor

Secondary Winding

Spark Plug

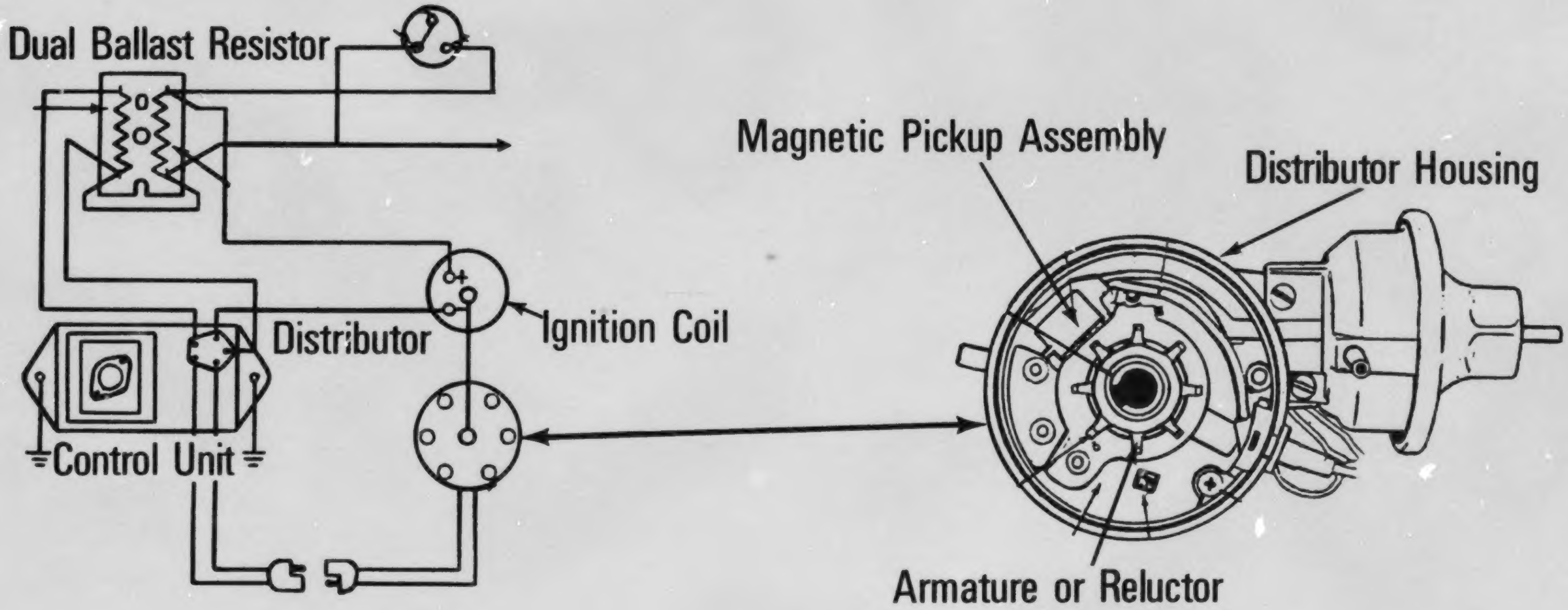
Ignition Coil

Distributor Cap

TM 9

D: ES-219

Major Components of an Electronic Ignition System


Dual Ballast Resistor
Distributor
Ignition Coil
Control Unit
Magnetic Pickup Assembly
Distributor Housing
Armature or Reluctor

IGNITION CIRCUITS
UNIT VI

JOB SHEET #1--REMOVE AND INSTALL A DISTRIBUTOR

I. Tools and materials

   A. Engine

   B. Basic hand tool set

   C. Set of ignition wrenches

   D. Special distributor wrenches as required

   E. Auxiliary starter button

   F. Spark plug socket wrench

   G. Shop towels

   H. Safety glasses

   I. Appropriate service manual

II. Procedure

(CAUTION: Remove all jewelry prior to working on electrical system and follow all shop safety procedures.)

   A. Remove distributor

      1. Remove air cleaner if required

      2. Remove the distributor wire from coil or distributor as required

      3. Remove the distributor cap and position out of the way

      4. Mark position of the rotor

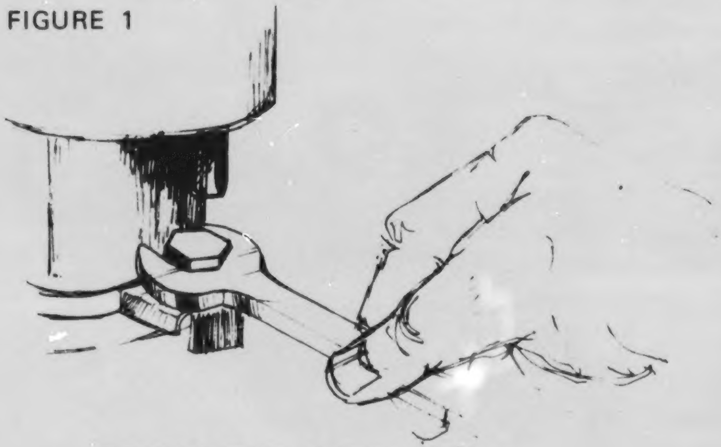
         (NOTE: It is necessary that the position be marked or indicated in some manner for re-installation.)

      5. Remove vacuum hose line from distributor

JOB SHEET #1

6. Remove distributor clamp screw and hold-down clamp (Figure 1)

FIGURE 1



REMOVE THIS CLAMP

7. Pull distributor up slowly and check direction the rotor turns

   (NOTE: The amount the rotor turns and the direction it turns will be necessary for re-installation.)

8. Remove distributor from engine

   (CAUTION: Avoid dropping bolts, brackets, or foreign material into opening. Cover with a shop towel.)

9. Service distributor as required

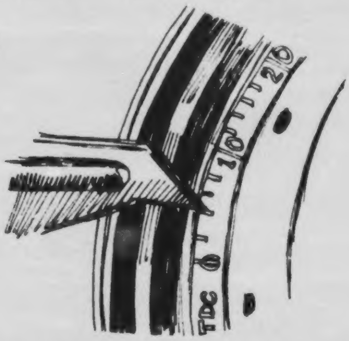
B. Install distributor

1. Remove number one cylinder spark plug
2. Install auxiliary starter button and crank the engine until compression is felt on number one cylinder

JOB SHEET #1

3. Crank the engine with short movements until the timing marks on the flywheel index with the timing marks on the front cover (Figure 2)

FIGURE 2



4. Place distributor in opening

   (NOTE: The rotor must be pointing in the same direction as it was before removal.)

5. Move distributor, if necessary, to engage the oil pump shaft

   (NOTE: Occasionally the distributor will not fall into place because the oil pump shaft has moved. The rotor should be positioned as close as possible to the beginning location and the engine rotated slightly until it falls into place. Some distributor drives will be driven by oil pump and gear mesh will not be necessary.)

6. Install hold-down clamp and clamp screw

7. Static time point openings

   (NOTE: A connection between distributor side of coil and ground with a light or buzzer can be used.)

8. Tighten the hold-down screw slightly

9. Replace vacuum lines

10. Replace distributor cap and wires if removed

11. Replace spark plugs and plug wires

12. Replace distributor lead wire

13. Check all connections for correct placement

14. Start engine and check timing

15. Check operation of automatic advance

IGNITION CIRCUITS
UNIT VI

JOB SHEET #2--REMOVE AND REPLACE CONTACT POINTS AND CONDENSER

I. Tools and materials

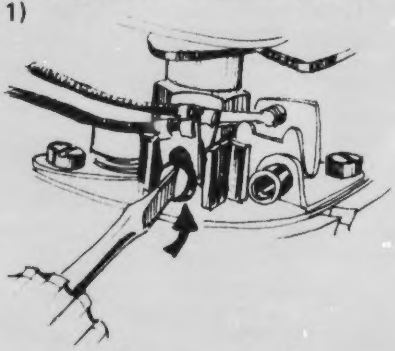
- A. Engine
- B. Basic hand tool set
- C. Ignition wrenches
- D. Feeler gauges, .010 - .025
- E. Distributor cam lubricant
- F. Point alignment tools
- G. Timing light
- H. Shop towels
- I. Safety glasses
- J. Appropriate service manual

II. Procedure

(CAUTION: Remove all jewelry prior to working on electrical system and follow all shop safety procedures.)

- A. Remove distributor cap
- B. Remove rotor
- C. Determine condition of contact points and location of wires, screws, and eccentric as used
- D. Disconnect contact point primary lead wire and condenser wire by loosening screw (Figure 1)

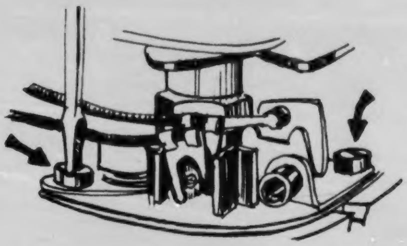
FIGURE 1



JOB SHEET #2

E. Loosen screws holding contact points in place (Figure 2)

FIGURE 2



F. Remove contact point set

G. Remove screw holding condenser in place

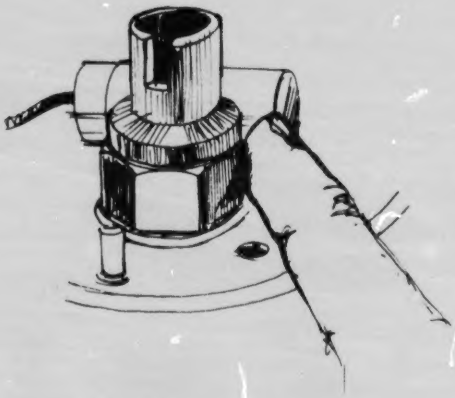
H. Remove condenser

I. Clean breaker plate and distributor cam

J. Lubricate the distributor cam with a light coat of cam lubricant (Figure 3)

(NOTE: On distributors with the centrifugal weights accessible, place a drop of light oil on each weight pivot post.)

FIGURE 3



K. Place the contact points in distributor and install attaching screws

L. Replace condenser and attaching screw; tighten securely

JOB SHEET #2

M. Replace the primary lead and condenser wires

(NOTE: Position the wires in such a manner to avoid binding or grounding.)

N. Tighten primary lead and condenser wires securely

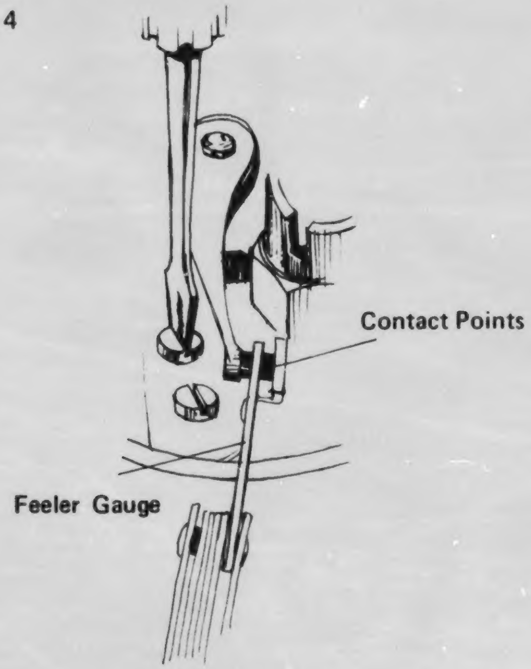
O. Check point alignment and adjust as required

P. Check contact point breaker spring tension

Q. Adjust contact point opening (Figure 4)

(NOTE: Crank the engine to position the rubbing block of the contact points on the peak of the cam lobe.)

FIGURE 4



R. Adjust contact points to manufacturer's recommendations

S. Tighten contact point attaching screws securely; recheck contact point opening

T. Install rotor

(NOTE: Make sure the rotor is positioned correctly and securely in place.)

JOB SHEET #2

U. Install distributor cap

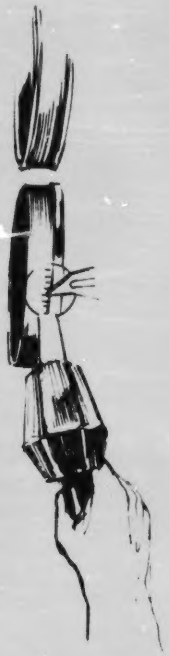
(NOTE: Make sure the distributor is positioned correctly and securely in place.)

V. Replace distributor in engine, if removed

W. Start engine

X. Set timing to manufacturer's specification (Figure 5)

FIGURE 5



TIMING

IGNITION CIRCUITS
UNIT VI

JOB SHEET #3--ADJUST DWELL ON AN EXTERNALLY ADJUSTABLE DISTRIBUTOR

I. Tools and materials

- A. Engine
- B. Dwell meter
- C. Hex contact point adjusting tool
- D. Safety glasses
- E. Appropriate service manual

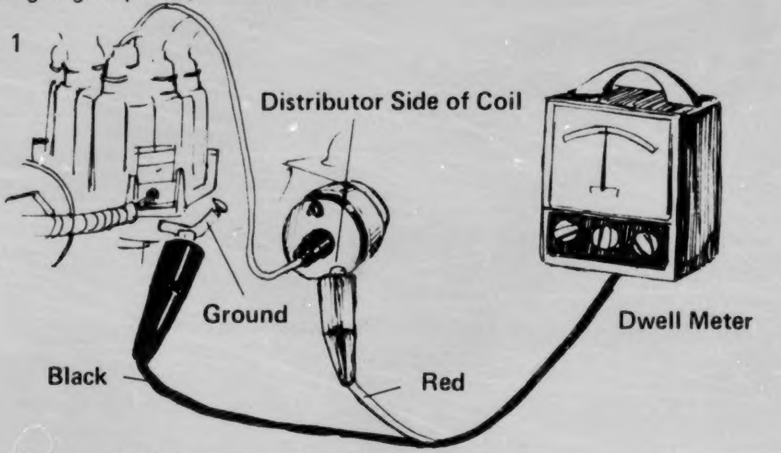
II. Procedure

(CAUTION: Remove all jewelry prior to working on electrical system and follow all shop safety procedures.)

A. Connect dwell meter (Figure 1)

(CAUTION: Observe correct hookup procedures and position wires away from moving engine parts.)

FIGURE 1



(NOTE: Be sure and disconnect vacuum line.)

B. Refer to manufacturer's specifications for desired dwell setting

C. Start the engine

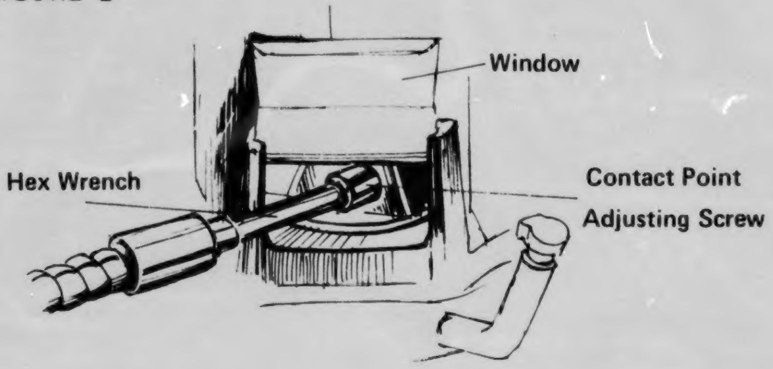
D. Adjust idle speed to manufacturer's specification

E. Raise distributor cap adjustment window

JOB SHEET #3

F. Insert hex wrench into contact point adjustment screw (Figure 2)

FIGURE 2


Window
Hex Wrench
Contact Point
Adjusting Screw

G. Adjust contact point dwell while observing dwell meter reading to comply with manufacturer's specifications

(NOTE: Recheck engine idle speed.)

H. Remove hex wrench and recheck dwell reading

I. Shut off the engine

J. Remove dwell meter

K. Push window on distributor cap down securely

(NOTE: Replace vacuum line to distributor.)

IGNITION CIRCUITS
UNIT VI

JOB SHEET #4--CHECK AND SET IGNITION TIMING

I. Tools and materials

- A. Engine
- B. Timing light
- C. Combination end wrenches, 7/16" - 9/16"
- D. Special distributor wrenches as required
- E. Chalk
- F. Shop towels
- G. Safety glasses
- H. Appropriate service manual

II. Procedure

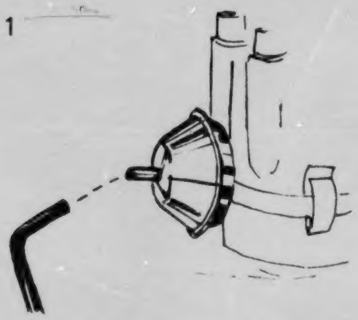
(CAUTION: Remove all jewelry prior to working on electrical system and follow all shop safety procedures.)

A. Obtain manufacturer's specifications for ignition timing, dwell, and rpm

(NOTE: Rpm and dwell must be set to manufacturer's specifications before timing is set.)

B. Remove vacuum line at the distributor (Figure 1)

FIGURE 1



REMOVE VACUUM LINE

JOB SHEET #4

C. Locate and clean the ignition timing marks on the harmonic balancer; mark with chalk

D. Locate and clean the timing pointer or plate on the front cover

E. Connect the timing light according to the instructions for the light being used

(NOTE: Do not puncture spark plug cables with pins or clips to make connections.)

F. Position wires away from moving engine parts

G. Start the engine

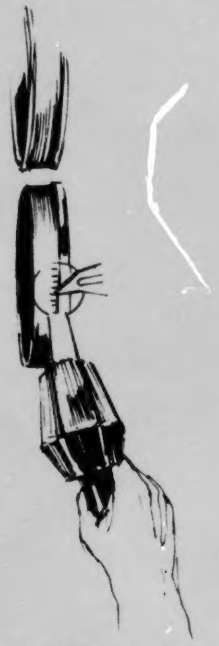
H. Make sure the engine is idling at manufacturer's recommendations

(NOTE: The engine must idle correctly to prevent incorrect timing caused by the centrifugal advance.)

I. Direct the timing light toward the timing marks (Figure 2)

(NOTE: If the timing is correct, the timing marks will line up at the check point. If the timing is incorrect, proceed as follows.)

FIGURE 2



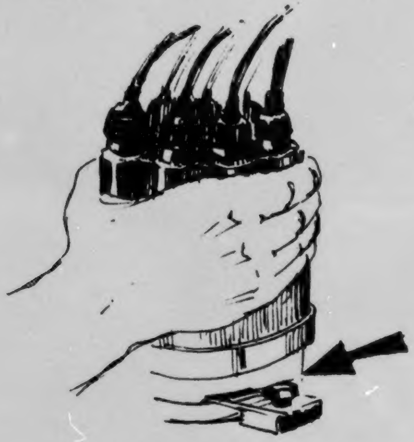
CHECK TIMING

J. Loosen the clamp or lock screw on the distributor

JOB SHEET #4

K. Move the distributor until the timing marks are lined up (Figure 3)

FIGURE 3



MOVE DISTRIBUTOR TO ADJUST TIMING

L. Tighten the clamp or lock screw on the distributor

M. Recheck timing

N. Shut off engine

O. Disconnect timing light

(NOTE: Remove timing light adapter on spark plug if used.)

P. Replace vacuum line on distributor

IGNITION CIRCUITS
UNIT VI

JOB SHEET #5--REMOVE, SERVICE, AND REPLACE SPARK PLUGS

I. Tools and materials

- A. Engine
- B. Spark plug socket, 3/8" drive
- C. Ratchet, 3/8" drive
- D. Extensions, 3" - 6" - 10" by 3/8" drive
- E. Spark plug cleaner
- F. Wire brush
- G. Small point file
- H. Shop towels
- I. Safety glasses
- J. Appropriate service manual

II. Procedure

(CAUTION: Remove all jewelry prior to working on electrical system and follow all shop safety procedures.)

A. Remove spark plug wires

(NOTE: Pull the wire from the spark plug by grasping the terminal, not by pulling on the wire.)

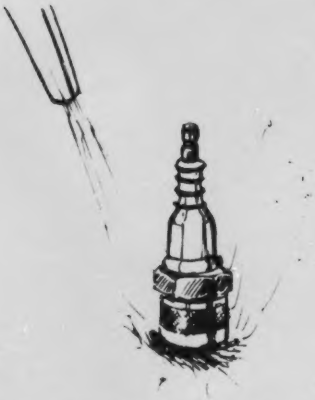
B. Loosen the spark plugs

C. Clean the area around the spark plug by blowing, wiping, or brushing (Figure 1)

(CAUTION: Protect your eyes when using compressed air.)

JOB SHEET #5

FIGURE 1

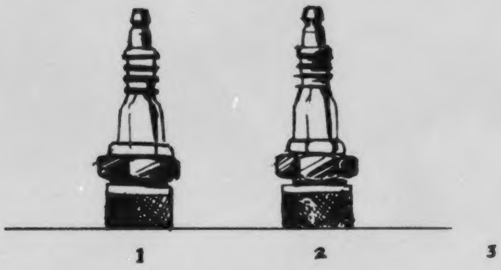


CLEAN AROUND SPARK PLUG

D. Remove the spark plugs

(NOTE: Arrange the spark plugs in order as they are removed. The condition of the spark plug can tell a lot about the operation of a particular cylinder. See Figure 2.)

FIGURE 2



ARRANGE IN ORDER

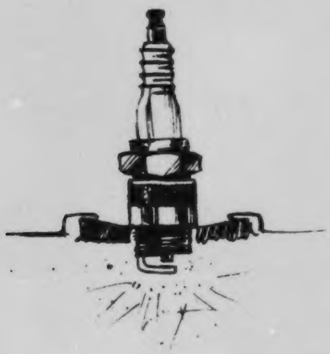
E. Remove the spark plug gaskets if used

F. Determine the condition of the spark plugs and decide whether to replace or service

JOB SHEET #5

G. Service by cleaning the spark plugs on a spark plug cleaning machine (Figure 3)

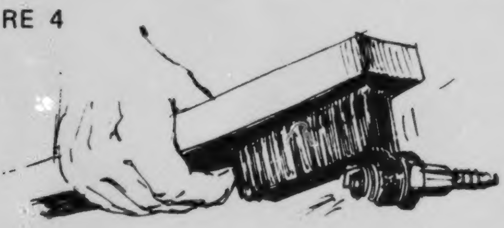
FIGURE 3



CLEAN SPARK PLUGS

H. Clean the threads with a wire hand brush (Figure 4)

FIGURE 4

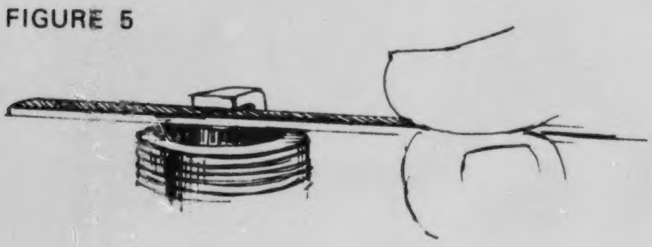


CLEAN SPARK PLUG THREADS

I. Bend the ground electrode slightly to open gap

J. File the center electrode to flatten the surface and square up the edges (Figure 5)

FIGURE 5



FILE CENTER ELECTRODE FLAT

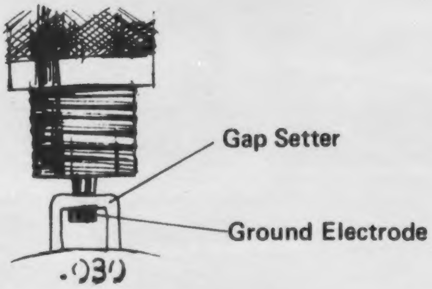
JOB SHEET #5

K. Reset gap on new and serviced spark plugs to manufacturer's specifications (Figure 6)

(NOTE: Use a wire gauge to check the gap. Make sure the electrode surfaces are parallel. Regap everytime plugs are serviced.)

(CAUTION: Bend only the ground electrode.)

FIGURE 6



RESET SPARK PLUG GAP

L. Install new spark plug gaskets as required

M. Install spark plugs and tighten

(NOTE: Use caution when starting the spark plugs to avoid cross threading.)

N. Torque the spark plugs to manufacturer's recommendations

O. Replace the spark plug wires in the proper order

(NOTE: Push the spark plug wires securely into place and make sure they are in the brackets or holders.)

IGNITION CIRCUITS
UNIT VI

NAME ____________________________

TEST

1. Match the terms on the right with their correct definitions.

_____a. Igniting the fuel-air mixture at the exact instant that will enable the engine to develop maximum power

_____b. Marks used to synchronize the ignition circuit so that plugs will fire at the precise time

_____c. Low voltage circuit which energizes the ignition coil

_____d. High voltage circuit which produces electrical current to jump spark plug gap

_____e. Number of degrees of distributor cam rotation that the ignition points are closed

_____f. A unit installed between the breaker points and coil to prevent arcing

_____g. A means of connecting the coil primary windings to the distributor so that current produced at the spark plug will travel from center electrode to ground

_____h. Ignition system using a control unit and magnetic pickup to open and close the primary circuit

_____i. A switching device that opens and closes the ignition to primary ground circuit

_____j. Rotating part in distributor that breaks the magnetic field in the pickup coil

1. Condenser
2. Timing marks
3. Electronic ignition system
4. Secondary ignition circuit
5. Dwell
6. Timing
7. Primary ignition circuit
8. Coil polarity
9. Electronic module
10. Stator

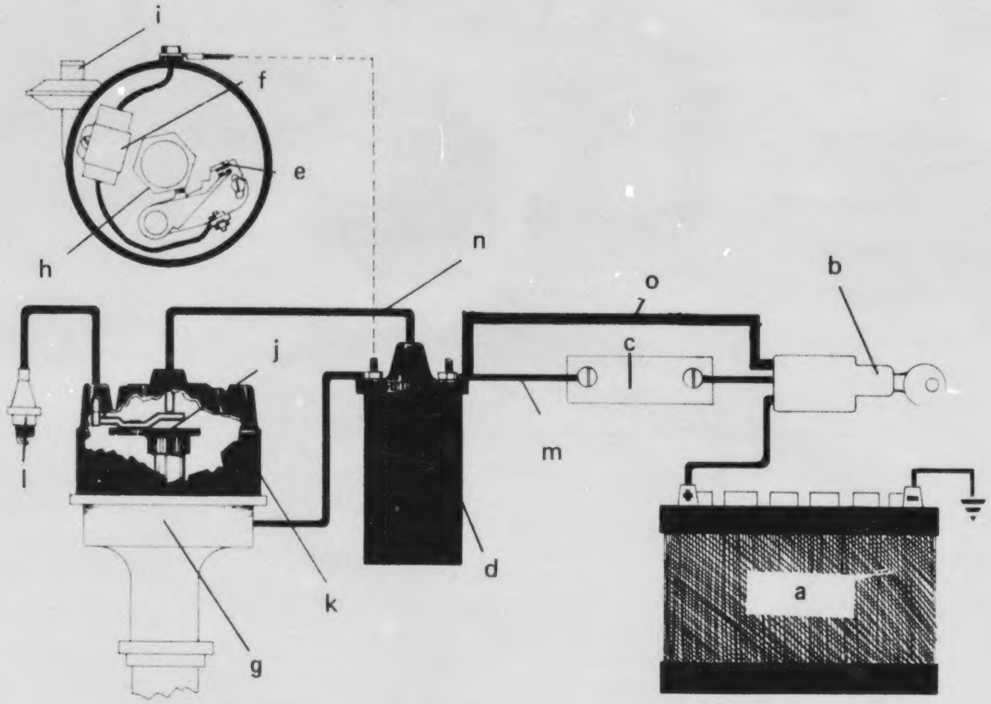
2. Explain the purpose of an ignition circuit.

____

____

____

3. Identify the components of an ignition circuit.


i
f
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a. ______________________

b. ______________________

c. ______________________

d. ______________________

e. ______________________

f. ______________________

g. ______________________

h. ______________________

i. ______________________

j. ______________________

k. ______________________

l. ______________________

m. ______________________

n. ______________________

o. ______________________

4. Match the components of an ignition circuit on the right with their correct functions.

______a. Source of electrical power

______b. Opens and closes the primary circuit between battery and contact points

______c. Reduces voltage in the primary circuit to protect the contact points

______d. Transforms low voltage into high voltage necessary to jump the spark plug gap

______e. Make and break the primary circuit to allow the coil to produce high voltage at the spark plugs

______f. Device that absorbs surges in the primary circuit when the opening of the ignition points causes an interruption in current flow

______g. Contains the contact points and condenser; distributes the high voltage current from the coil to the proper cylinder

______h. Opens and closes the contact points

______i. Regulates the timing of the high voltage circuit for best ignition during all speed and load conditions

______j. Takes the high voltage current from the coil and directs it to the correct cylinder

______k. Holds the coil and spark plug wires in a sequence and provides a cover for the distributor

______l. Provides a spark gap inside the engine cylinder to ignite the fuel-air mixture

______m. Carries low voltage from the battery to the primary side of the ignition coil (light wire)

______n. Carries high voltage from the secondary side of the coil to the spark plug (heavily insulated wire)

______o. Primary ignition circuit that bypasses the ignition resistance unit, permitting full battery voltage to the ignition coil during starting only

1. Ignition switch
2. Primary resistance unit
3. Spark plug
4. Primary ignition wire
5. Breaker cam
6. Distributor
7. Secondary ignition cable
8. Distributor cap
9. Spark-advance mechanism
10. Condenser
11. Ignition coil
12. Rotor
13. Contact points
14. Battery
15. Ignition bypass circuit

5. Distinguish between primary and secondary ignition circuit components by placing a "P" next to primary components and a "S" next to secondary components.

______a. Resistance unit

______b. Condenser

______c. Distributor cap

______d. Ignition switch

______e. Rotor

______f. Secondary winding of the coil

______g. High voltage wire that connects the units

______h. Low voltage wire that connects the units

______i. Contact points

______j. Battery

______k. Primary winding of the coil

______l. Spark plug

6. Identify the components of a distributor.

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

e. ______________________________

f. ______________________________

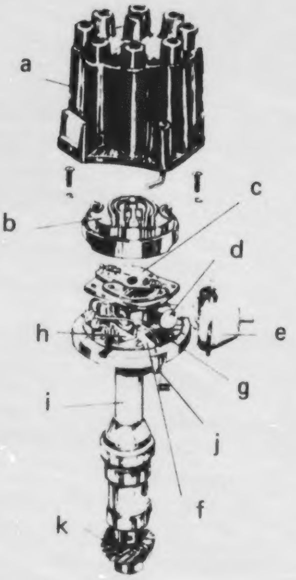
g. ______________________________

h. ______________________________

i. ______________________________

j. ______________________________

k. ______________________________



7. Arrange in order the steps in the operation of an ignition circuit beginning with the battery through one complete cycle by placing the correct sequence number in the appropriate blank.

______a. As the contact points open, current attempts to flow across the point surfaces; the condenser attached to the points absorbs this flow of current

______b. This high voltage surge is directed from the secondary windings of the coil through the distributor cap and rotor and on to the spark plug to ground

______c. The flow of low voltage current through the primary windings of the coil causes a magnetic field buildup

______d. Stopping this flow of current causes the magnetic field of the coil to collapse across the secondary coil windings, causing a high voltage surge

______e. With the ignition switch on and the contact points closed, low voltage current flows from the battery through the primary winding of the coil and through the contact points to ground

8. Distinguish between transistorized and capacitive discharge ignition systems by placing an "X" next to the descriptions of transistorized ignitions.

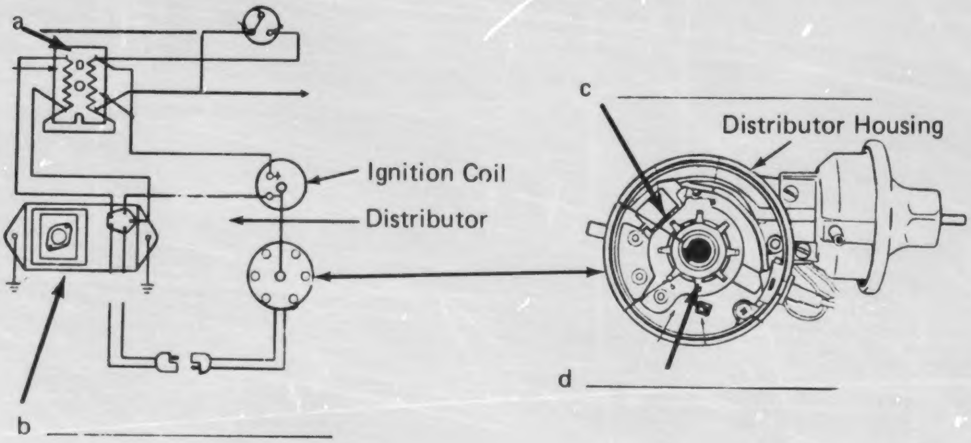
______a. System contains special ignition distributor, amplifier, and special coil

______b. Transistors allow very low voltage through the points and very high voltage to the primary windings in coil

______c. Amplifier included in circuit between points and ignition coil

______d. System operates to charge a capacitor to a high voltage which, on signal from distributor, is then discharged through the primary windings in coil

9. Identify the major components of an electronic ignition system.



10. Match the major components of an electronic ignition system on the right with the functions.

    ______a. Maintains constant primary current with variations in engine speed

    ______b. Sends a small voltage pulse to the control unit to trigger switching transistor to stop current flow in the coil primary windings

    ______c. Rotates with the distributor shaft, producing a voltage pulse in the magnetic pickup

    ______d. Controls the flow of current in the primary windings of the ignition coil and maintains constant dwell

    1. Magnetic pickup assembly
    2. Control unit
    3. Armature or reluctor
    4. Dual ballast resistor

11. Demonstrate the ability to:

    a. Remove and install a distributor.

    b. Remove and replace contact points and condenser.

    c. Adjust dwell on an externally adjustable distributor.

    d. Check and set ignition timing.

    e. Remove, service, and replace spark plugs.

    (NOTE: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

IGNITION CIRCUITS
UNIT VI

ANSWERS TO TEST

1. a. 6
   b. 2
   c. 7
   d. 4
   e. 5
   f. 1
   g. 8
   h. 3
   i. 9
   j. 10

2. Explanation should include--The ignition circuit produces a high voltage spark which ignites the fuel-air mixture in the engine cylinder

3. a. Battery
   b. Ignition switch
   c. Primary resistance unit
   d. Ignition coil
   e. Contact points
   f. Condenser
   g. Distributor
   h. Breaker cam
   i. Spark-advance mechanism
   j. Rotor
   k. Distributor cap
   l. Spark plug
   m. Primary ignition wire
   n. Secondary ignition wire
   o. Ignition bypass circuit

4. a. 14
   b. 1
   c. 2
   d. 11
   e. 13
   f. 10
   g. 6
   h. 5
   i. 9
   j. 12
   k. 8
   l. 3
   m. 4
   n. 7
   o. 15

5. a. P
   b. P
   c. S
   d. P
   e. S
   f. S
   g. S
   h. P
   i. P
   j. P
   k. P
   l. S

6. a. Distributor cap
   b. Rotor
   c. Centrifugal advance mechanism
   d. Condenser
   e. Vacuum advance unit
   f. Breaker plate
   g. Distributor cam
   h. Contact points
   i. Distributor housing
   j. Primary lead wire
   k. Distributor drive gear

7. a. 3
   b. 5
   c. 2
   d. 4
   e. 1

8. b, c

9. a. Dual ballast resistor
   b. Control unit
   c. Magnetic pickup assembly
   d. Armature or reluctor

10. a. 4
    b. 1
    c. 3
    d. 2

11. Performance skills evaluated to the satisfaction of the instructor

GENERATOR CHARGING CIRCUITS
UNIT VII

UNIT OBJECTIVE

After completion of this unit, the student should be able to identify the major parts of a generator and match the names of components in the DC charging circuit with their correct functions. The student should also be able to disassemble, test, and reassemble a generator. This knowledge will be evidenced by correctly performing the procedures outlined in the job sheets and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to generator charging circuits with their correct definitions.
2. State the purpose of a generator charging circuit.
3. Name two kinds of charging circuits.
4. Match the names of the components in the DC charging circuit with their functions.
5. Identify the major parts of a generator.
6. Select true statements concerning the three operating stages of a charging circuit.
7. Arrange in order the steps in which current flows in a basic generator.
8. Explain how a field circuit is created in a generator.
9. Complete a list of statements concerning how a generator converts AC to DC current.
10. Distinguish between an "A" generator field circuit and a "B" generator field circuit.
11. Match the names of the generator regulator components with their correct functions.
12. Match the types of generators with their uses.
13. Match the types of electrical failure with their causes.
14. Select true statements concerning reverse polarity.

15. Demonstrate the ability to:
    - a. Test generator output.
    - b. Remove and replace a generator.
    - c. Disassemble, test, and reassemble a generator.
    - d. Test and adjust a regulator unit.

GENERATOR CHARGING CIRCUITS
UNIT VII

SUGGESTED ACTIVITIES

I. Provide student with objective sheet.

II. Provide student with information and job sheets.

III. Make transparencies.

IV. Discuss unit and specific objectives.

V. Discuss information sheet.

VI. Demonstrate and discuss the procedures outlined in the job sheets.

VII. Demonstrate lathe turning of a commutator.

VIII. Demonstrate an alternator and generator to show difference in output.

IX. Discuss electrical cautions.

X. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

   A. Objective sheet

   B. Information sheet

   C. Transparency masters

      1. TM 1--Kinds of Charging Circuits
      2. TM 2--Parts of a Generator
      3. TM 3--Stages of Charging Circuit
      4. TM 4--Current Flow in Basic Generator
      5. TM 5--AC Converts to DC
      6. TM 6--External Generator Regulator and Cut-Out Relay
      7. TM 7--External Generator Regulator and Cut-Out Relay (Continued)
      8. TM 8--Types of Generators

D. Job sheets

   1. Job Sheet #1--Test Generator Output

   2. Job Sheet #2--Remove and Replace a Generator

   3. Job Sheet #3--Disassemble, Test, and Reassemble a Generator

   4. Job Sheet #4–Test and Adjust a Regulator Unit

E. Test

F. Answers to test

II. References:

A. *Fundamentals of Service: Electrical Systems.* Fourth Edition. Moline, IL: Deere and Company, 1979.

B. Stockel, Martin W. *Auto Service and Repair*. Homewood, IL: Goodheart-Willcox Company, 1969.

C. Billiet, Walter E., and Leslie F. Goings. *Automotive Electrical Systems.* Third Edition. Chicago: American Technical Society, 1970.

D. Dagel, John F. *Diesel Engine Repair*. New York: John Wiley and Sons, Inc., 1982.

E. Foutes, William A. *Diesel Engine Mechanics.* Stillwater, OK: Mid-America Vocational Curriculum Consortium, 1977.

GENERATOR CHARGING CIRCUITS
UNIT VII

INFORMATION SHEET

I. Terms and definitions

   A. Armature--Series of wire conductors in the form of a loop, rotating in a stationary magnetic field

   B. Commutator--Bars on end of armature drive shaft and connected to the ends of each wire conductor

   C. Pole shoes--Permanent magnets that are fixed to the inside of generator housing, and set opposite each other to create a weak magnetic field

   D. Field circuit--One wire conductor wound around both poles many times and attached to the brush

   E. Regulator--An assembly which houses the cut-out relay, voltage regulator, and current regulator

   F. Arcing--Current attempting to cross between the commutator sections and the brush

   G. Polarity--Direction of current flow through the generator

   H. Open circuit--Circuit in which a wire is broken or disconnected

   I. Short circuit--Wire touching another wire and providing a shorter path for current to flow

   J. Grounded circuit--Circuit in which a wire touches ground causing the current to flow to ground instead of through the circuit

II. Purpose of a generator charging circuit-- The generator charging circuit recharges the battery and generates current during operation of the engine

III. Kinds of charging circuits (Transparency 1)

   (NOTE: Both circuits generate an alternating current, but differ in how they rectify the alternating current to direct current.)

   A. Direct current

      (NOTE: Direct current charging circuits are associated with generator type systems.)

INFORMATION SHEET

B. Alternating current

(NOTE: Alternating current charging circuits are associated with alternator type systems.)

IV. Components of the DC charging circuit and their functions (Transparency 1)

A. Battery

1. Starts the circuit by supplying spark to start engine
2. Helps out during peak operation when electrical loads are too much for generator or alternator
3. Stabilizes voltage in system

B. Generator

1. Supplies electrical power to accessory circuits
2. Recharges battery

C. Regulator

1. Opens and closes the charging circuit (cut-out relay)
2. Prevents overcharging of battery (voltage regulator)
3. Limits the generator's output to safe rates (current regulator)

D. Ammeter--Measures the rate of current flow

E. Voltmeter--Indicates produced voltage

V. Parts of a generator (Transparency 2)

A. Pulley

B. Fan

C. Drive end frame

D. Generator housing

E. Field coils

F. Commutator

INFORMATION SHEET

  G. Thru bolts

  H. Brushes

  I. Armature

VI. Operating stages of a charging circuit (Transparency 3)

  A. Starting--Battery supplies all load current

  B. Peak operation--Battery helps generator supply current

  C. Normal operation--Generator supplies all current and recharges battery

VII. Current flow in a basic generator (Transparency 4)

(NOTE: The armature rotates through the magnetic field of the poles generating voltage.)

  A. Current flows from armature loop to the commutator ring

  (NOTE: The left end of the armature loop is positive while the right end is negative.)

  B. Current flows from the commutator ring through brushes to a wire connected to a load

  C. Current flows when circuit is complete

VIII. Field circuit wiring--Wire conductors are wound around the magnets (magnetic poles) and connected to the brushes to strengthen the field (Transparency 4)

IX. AC converted to DC current (Transparency 5)

  A. The commutator is split in two parts creating a gap as the commutator passes the brushes

  (NOTE: This is called the static neutral point where no voltage is created.)

  B. Past this point the other half of the commutator contacts the brushes reversing the current flow

  C. At the same time the rotating armature reverses its polarity converting AC to DC

X. "A" and "B" generator field circuits

  A. "A" generator field circuit--Current flows from the armature circuit through the field to the regulator, then to ground

INFORMATION SHEET

B. "B" generator field circuit--Current flows from the regulator through the field coils to ground

(NOTE: "B" circuits are seldom used in farm and industrial machines.)

XI. Functions of the generator regulator components (Transparencies 6 and 7)

A. Cut-out relay--An automatic switch which closes when generator is running for battery charging and opens when generator stops to prevent battery discharge

B. Voltage regulator--Controls the amount of voltage the regulator produces through a shunt coil and contact points controlling the strength of the magnetic field; prevents overheating

C. Current regulator--Controls the current flow similar to the voltage regulator

(NOTE: Both the voltage regulator and the current regulator are used but while one is working the other is not.)

XII. Types and uses of generators (Transparency 8)

A. Shunt--Used as a standard generator for most normal operations

B. Third brush--Eliminates the use of a current regulator, is relatively easy to change third brush position and control the output, and is used in systems with low speed and low load requirements

C. Interpole--Provides a better commutation point and extends brush life

D. Bucking field--Used where there is a wide variation of load and speed requirements

E. Split field--Used in systems with low speed, but high load requirements

XIII. Types and causes of electrical failure

A. Short circuits--Unwanted connections, usually copper-to-copper, that allow current to bypass all or part of the circuit

B. Open circuits--Breaks in the circuit which cause extremely high resistance

(NOTE: Usually no current will flow through an open circuit.)

INFORMATION SHEET

C. Grounded circuits--Unwanted connections that bypass all or part of the circuit from the insulated side to the grounded side

(NOTE: A grounded circuit is usually a copper-to-iron connection.)

D. High resistance circuits--Usually caused by poor or corroded connections and frayed or damaged wires, creating greater resistance in the circuit

XIV. Reverse polarity

A. Generator polarity is opposite that of the battery

B. Battery is in series with the generator

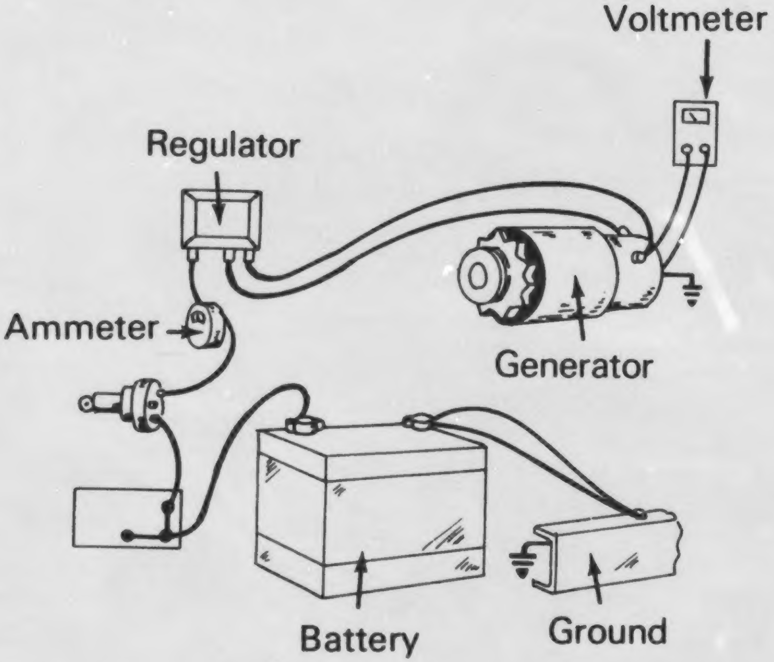
C. Generator builds up voltage and closes the cut-out relay points

D. High voltage can create enough current and heat to weld the points together

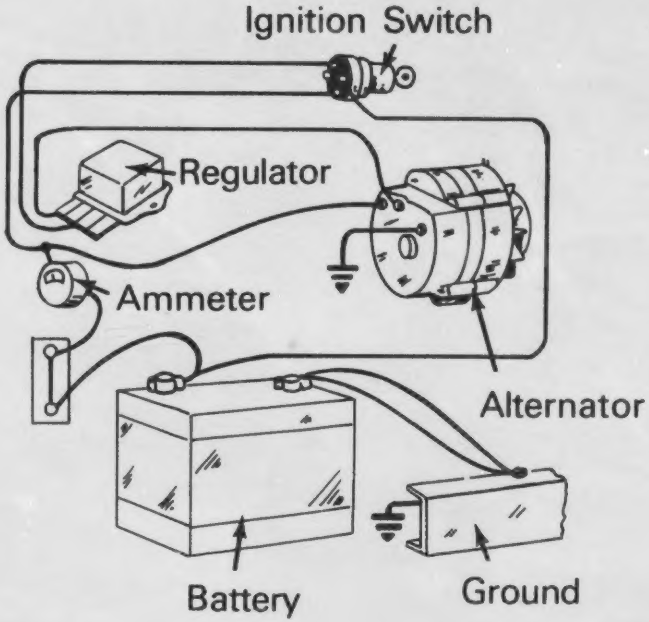
(CAUTION: After any service, polarize the DC generator.)

(NOTE: Pole shoe polarity is determined by the magnetism of the field coils the last time current passed through the coils; a slight current through the field coils when servicing can accidentally change pole polarity.)

Kinds Of Charging Circuits

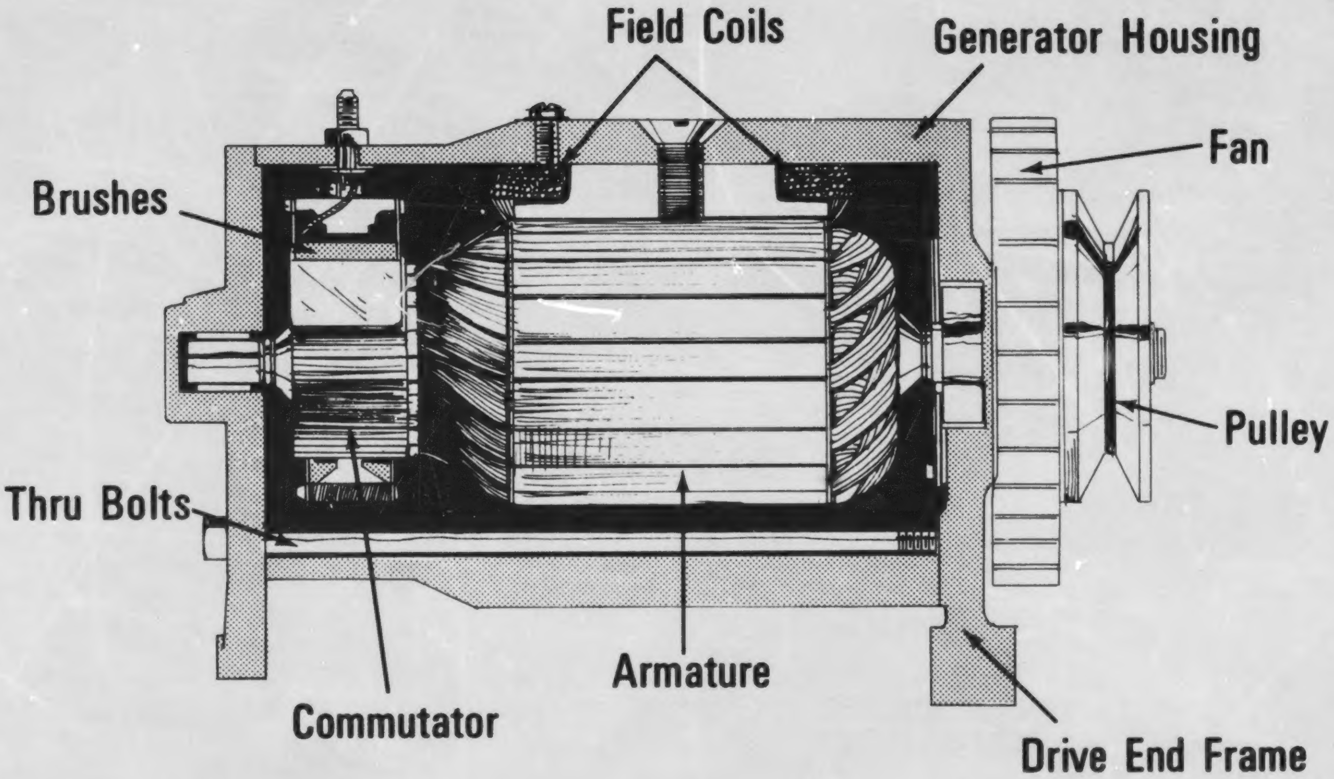

Voltmeter
Regulator
Ammeter
Generator
Battery
Ground

GENERATOR


Ignition Switch
Regulator
Ammeter
Alternator
Battery
Ground

ALTERNATOR

Parts of a Generator


Field Coils
Generator Housing
Fan
Brushes
Pulley
Thru Bolts
Armature
Commutator
Drive End Frame

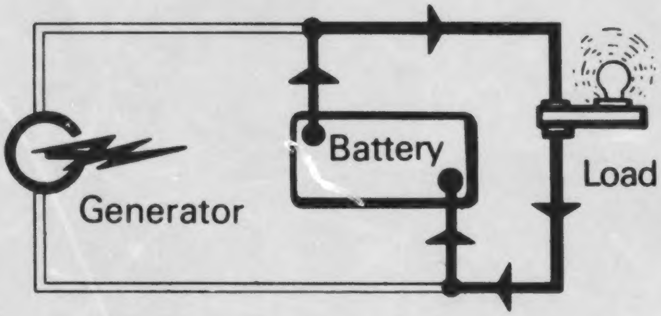
TM 2

252

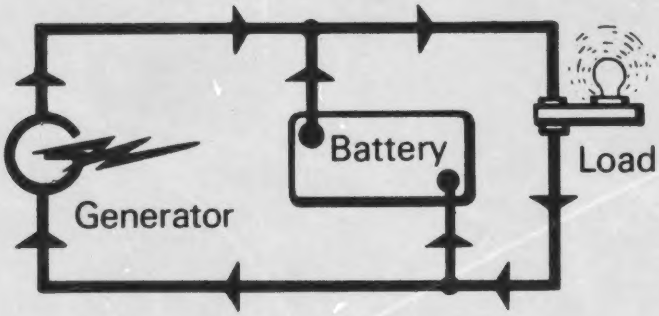
253

D: ES-261

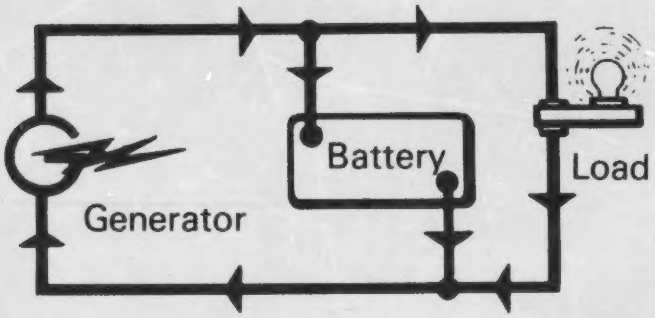
Stages Of Charging Circuit


Battery
Load
Generator

BATTERY SUPPLYING LOAD CURRENT

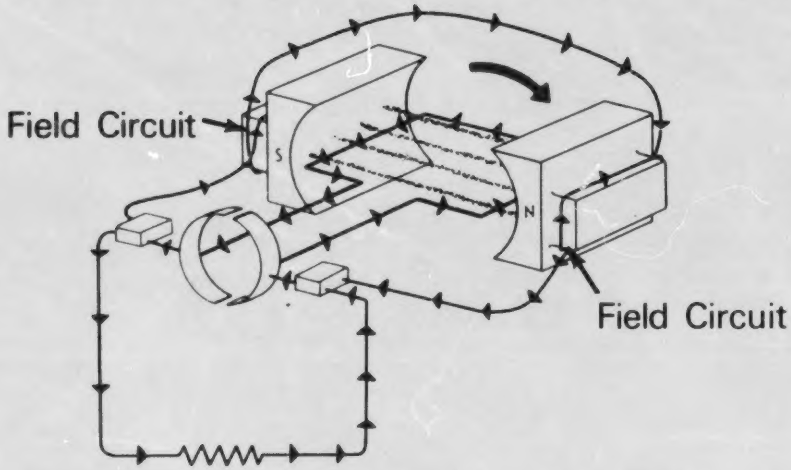

Battery
Load
Generator

GENERATOR AND BATTERY
SUPPLYING LOAD CURRENT

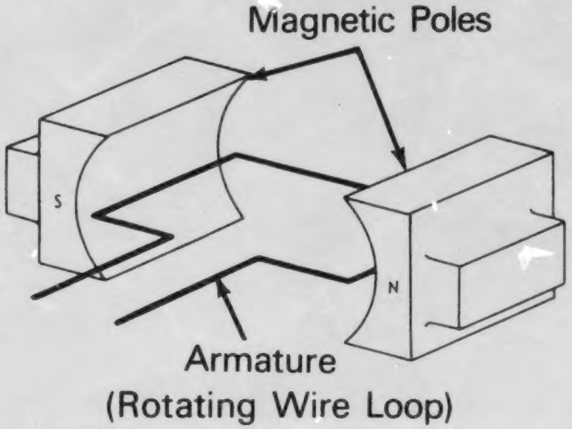

Battery
Load
Generator

GENERATOR SUPPLYING LOAD
CURRENT AND CHARGING BATTERY

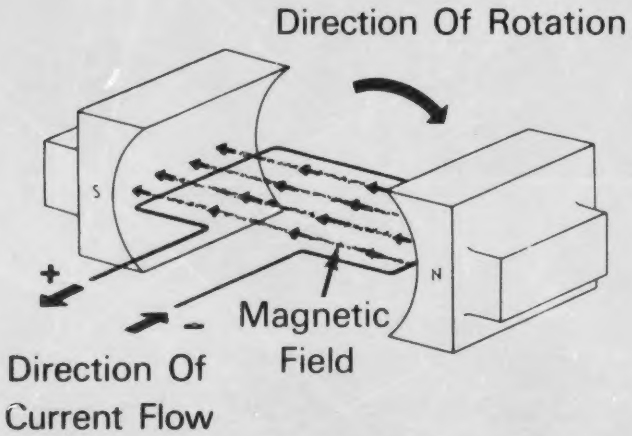
Current Flow In Basic Generator


Field Circuit
S
N
Field Circuit

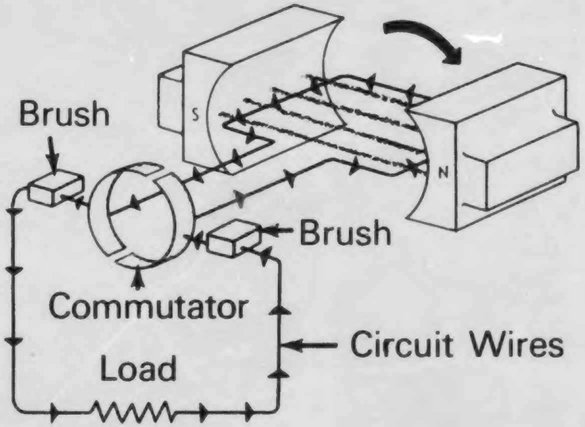
COMPLETE PARTS OF BASIC GENERATORS


Magnetic Poles
S
N
Armature
(Rotating Wire Loop)

THE BASIC PARTS OF A GENERATOR


Direction Of Rotation
S
N
+
-
Magnetic
Field
Direction Of
Current Flow

BASIC GENERATED VOLTAGE

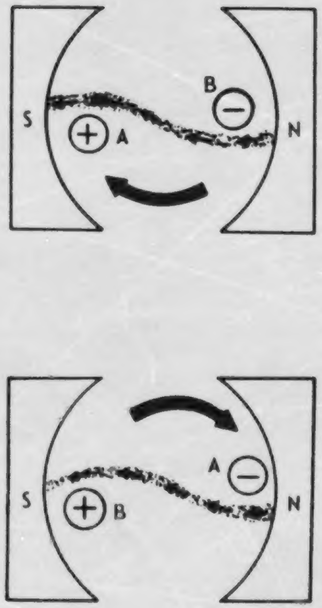

Brush
S
N
Brush
Commutator
Circuit Wires
Load

BASIC CURRENT FLOW IN GENERATOR

TM 4

D: ES-265

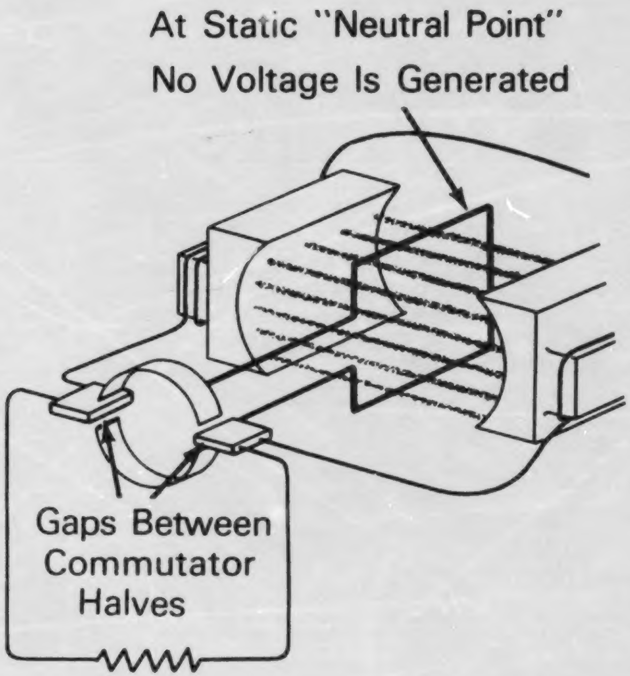
AC Converts To DC



First Half
Of Revolution

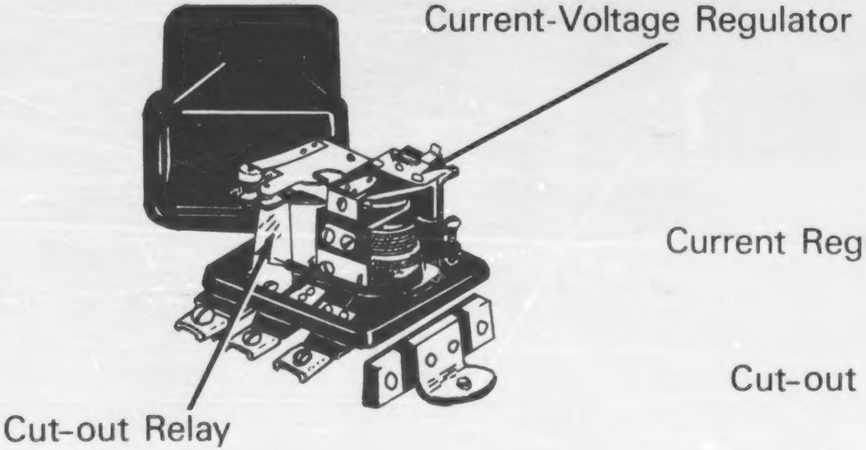
Second Half
Of Revolution

HOW THE POLARITY OF THE ARMATURE CHANGES DURING EACH REVOLUTION

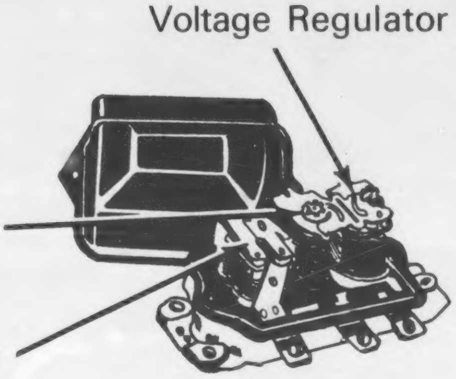

At Static "Neutral Point"
No Voltage Is Generated
Gaps Between
Commutator
Halves

HOW GENERATOR CONVERTS A.C. TO D.C. CURRENT

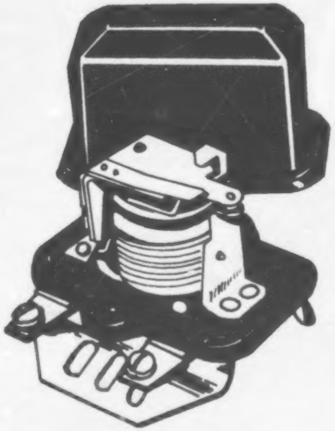
External Generator Regulator And Cut-Out Relay


Current-Voltage Regulator
Cut-out Relay

CUT-OUT RELAY
CURRENT-VOLTAGE REGULATOR


Voltage Regulator
Current Regulator
Cut-out Relay

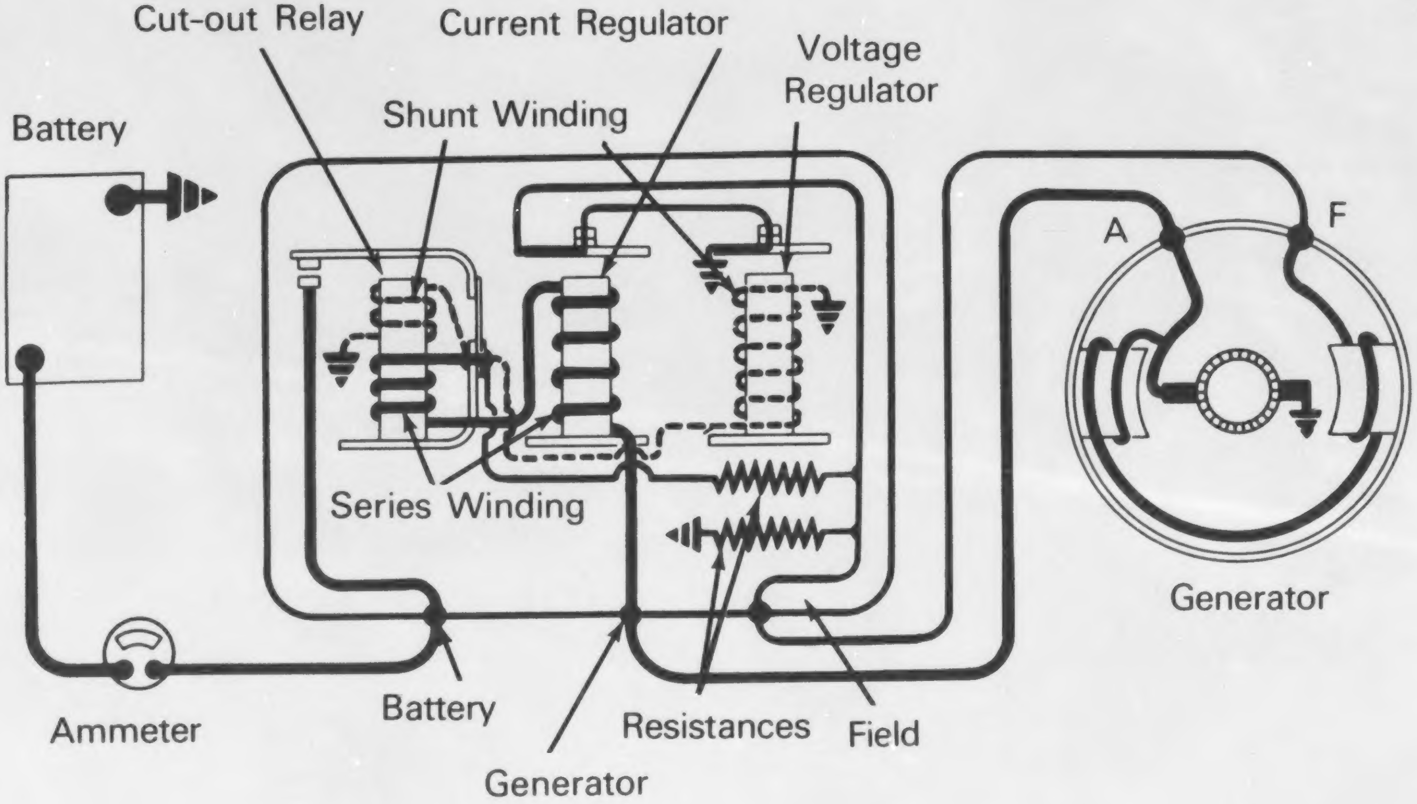
CUT-OUT RELAY,
CURRENT REGULATOR
AND
VOLTAGE REGULATOR



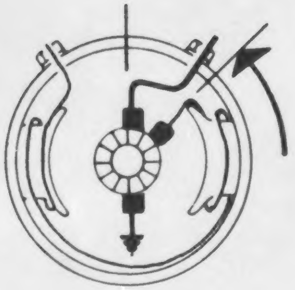
CUT-OUT RELAY

External Generator Regulator And Cut-Out Relay

(Continued)


Cut-out Relay
Current Regulator
Voltage Regulator
Shunt Winding
Battery
A
F
Series Winding
Generator
Ammeter
Battery
Resistances
Field
Generator

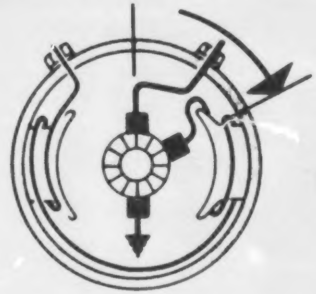
Types Of Generators



Higher Output

Increased Voltage
Increased Current
Greater Magnetic
Strength

FIELD

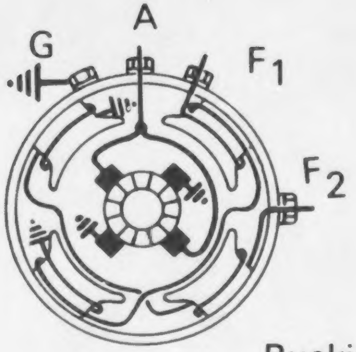


Lower Output

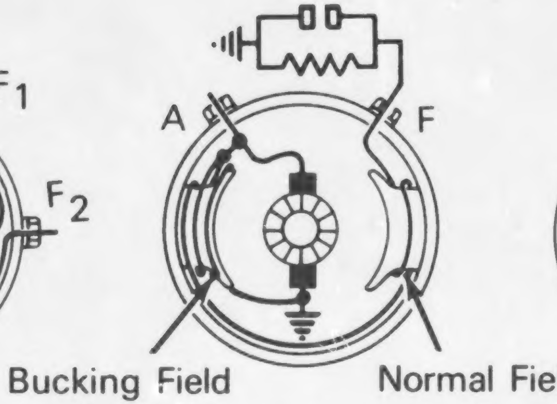
Reduced Voltage
Decreased Current
Less Magnetic
Strength

FIELD

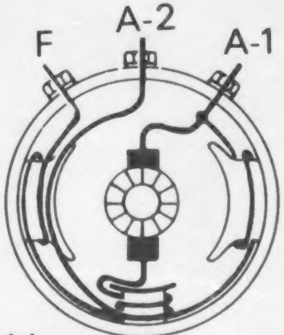
THIRD BRUSH



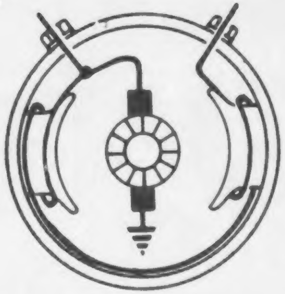
SPLIT FIELD


A
F
Bucking Field
Normal Field

BUCKING FIELD



INTERPOLE



SHUNT

GENERATOR CHARGING CIRCUITS
UNIT VII

JOB SHEET #1--TEST GENERATOR OUTPUT

I. Tools and materials

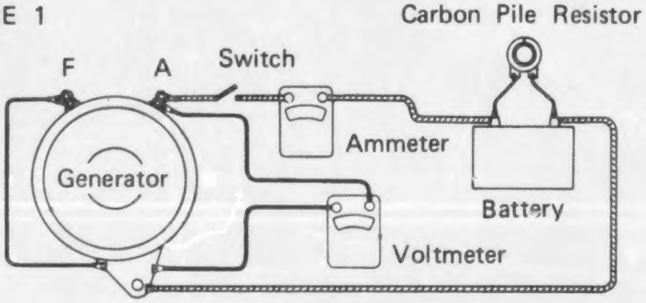
- A. Generator
- B. Battery
- C. Basic hand tool set
- D. Switch
- E. Ammeter
- F. Voltmeter
- G. Carbon pile
- H. Jumper leads
- I. Generator specifications manual
- J. Safety glasses
- K. Appropriate service manual

II. Procedure

(CAUTION: Remove all jewelry prior to working on any electrical system and follow all shop safety procedures.)

A. Connect an ammeter and switch in series with a battery to the generator output terminal (Figure 1)

FIGURE 1


Carbon Pile Resistor
F
A
Switch
Ammeter
Generator
Battery
Voltmeter

TESTING THE GENERATOR OUTPUT

JOB SHEET #1

B. Connect a voltmeter from the generator output terminal to ground (Figure 1)

C. Connect a carbon pile across the battery (Figure 1)

D. Connect a jumper lead to the generator field terminal (Figure 1)

E. Operate the generator to obtain battery voltage and close the switch

F. Speed up the generator to its rated value, and adjust the carbon pile to obtain the specified voltage

G. Compare the current output with the generator specifications

H. Disassemble generator for further testing if output is below par

(NOTE: The output test shown in Figure 1 is for the common "A" circuit generator. For "B" circuit models, a different test hookup is used.)

GENERATOR CHARGING CIRCUITS
UNIT VII

JOB SHEET #2--REMOVE AND REPLACE A GENERATOR

I. Tools and materials

- A. Vehicle
- B. Basic hand tool set
- C. Belt tension gauge
- D. Battery cable puller
- E. Shop towels
- F. Safety glasses
- G. Appropriate service manual

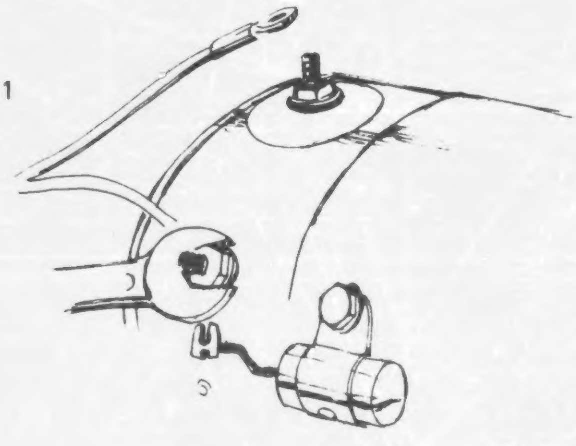
II. Procedure

(CAUTION: Remove all jewelry prior to working on any electrical system and follow all shop safety procedures.)

(NOTE: Always disconnect battery ground cable before working on charging circuits.)

A. Remove the leads from the generator terminals (Figure 1)

FIGURE 1

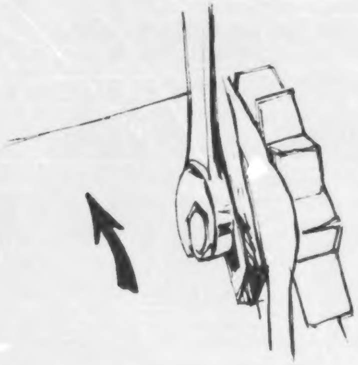


B. Remove the generator belt adjusting bolt from the generator

JOB SHEET #2

C. Move the generator toward the engine (Figure 2)

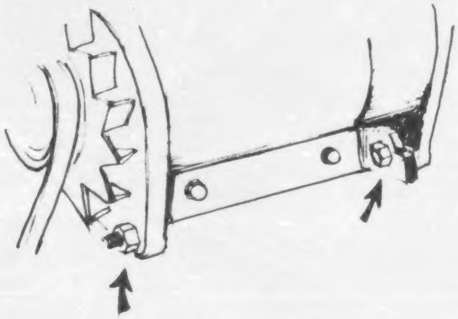
FIGURE 2



D. Remove the generator belt from the generator pulley

E. Remove the bolts holding the generator to the engine mounting bracket (Figure 3)

FIGURE 3



F. Lift the generator out of the bracket

G. Service the generator as required

H. Replace by positioning the generator in the engine mounting bracket

I. Start generator retaining bolts and tighten securely

J. Position generator belt on pulley and move generator away from engine to tighten belt

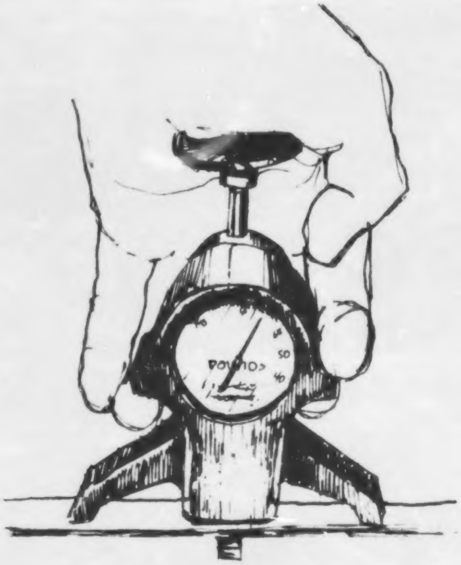
K. Install generator adjusting bolt

JOB SHEET #2

L. Pry the generator away from engine to adjust generator belt and tighten adjustment bolt

M. Check generator belt tension with a belt tension gauge and adjust to manufacturer's specifications (Figure 4)

FIGURE 4



CHECK BELT FOR TIGHTNESS

N. Install wire leads that were removed from generator

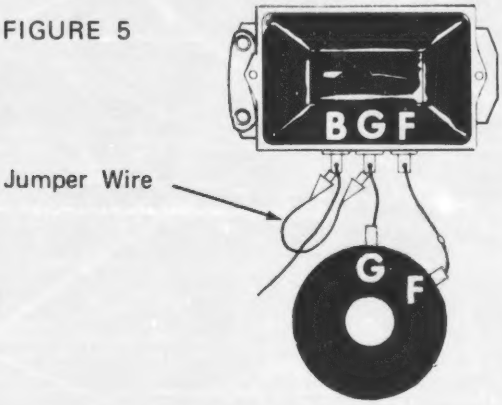
(NOTE: On installations using the condenser on generator, the condenser lead is attached to the "A" terminal, never the "F" terminal.)

JOB SHEET #2

O. Polarize the generator before starting engine

1. Polarize negative grounded circuit generators by holding one end of a jumper wire against the regulator BAT terminal, and scratch the other end of the jumper wire on the regulator GEN terminals (Figure 5)

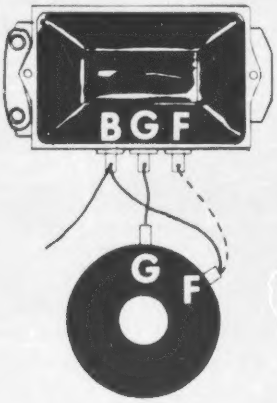
FIGURE 5



"A" CIRCUIT

2. Polarize positive grounded circuit generators by removing the lead from the FIELD terminal of the regulator and strike (or momentarily touch) the F-lead to the BAT terminal of the regulator (Figure 6)

FIGURE 6



"B" CIRCUIT

GENERATOR CHARGING CIRCUITS
UNIT VII

JOB SHEET #3--DISASSEMBLE, TEST, AND REASSEMBLE A GENERATOR

I. Tools and materials

- A. Generator
- B. Basic hand tool set
- C. Growler
- D. Test lamp or volt-ohmmeter
- E. Generator pulley puller
- F. Ball bearing grease
- G. Hacksaw blade
- H. Spring tension gauge
- I. Shop towels
- J. Safety glasses
- K. Appropriate service manual

II. Procedure

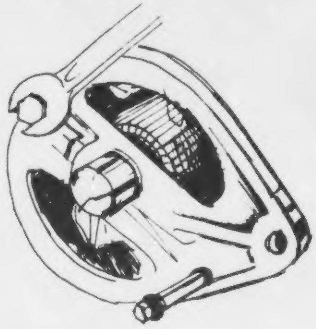
(CAUTION: Remove all jewelry prior to working on any electrical system and follow all shop safety procedures.)

A. Disassemble generator

(NOTE: Scribe generator case before separating.)

1. Remove generator thru bolts (Figure 1)

FIGURE 1

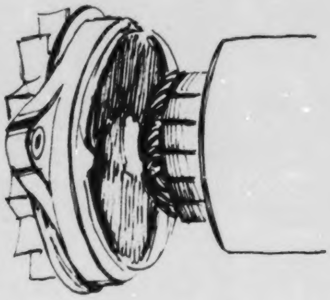


REMOVE THRU BOLTS

JOB SHEET #3

2. Tap the generator commutator end frame lightly and remove from housing
3. Remove the drive end frame and armature assembly from the generator housing (Figure 2)

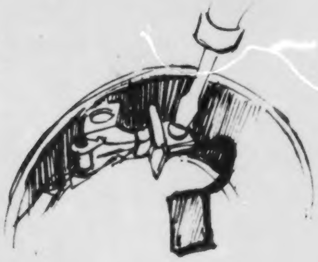
FIGURE 2



REMOVE DRIVE END FRAME AND ARMATURE ASSEMBLY

4. Remove the generator brushes (Figure 3)

FIGURE 3



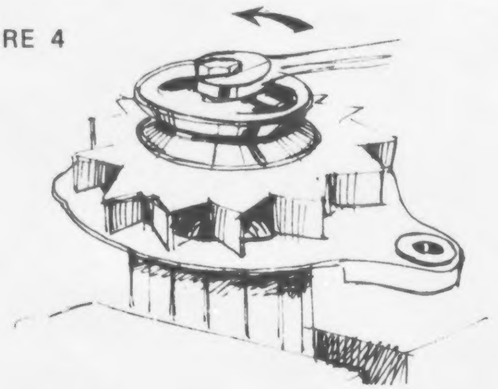
REMOVE BRUSHES

JOB SHEET #3

5. Place the armature and drive end frame assembly in a vise (Figure 4)

   (NOTE: Use brass jaws on vise.)

FIGURE 4

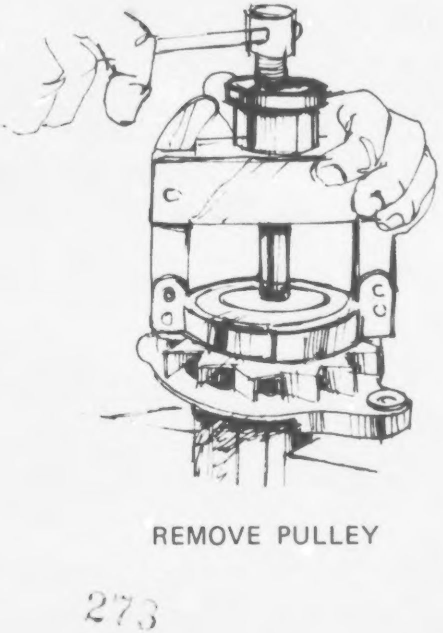


REMOVE PULLEY NUT

6. Remove the pulley nut

7. Remove the pulley from the armature using a pulley puller as required (Figure 5)

FIGURE 5



REMOVE PULLEY

JOB SHEET #3

8. Slide the drive end frame and spacer columns off armature shaft
9. Remove armature from vise
10. Remove bearing retainer and gasket from drive end frame
11. Remove drive end bearing from drive end frame

B. Service and test

1. Clean all generator components

   (NOTE: Do not wash the fields or armature with a degreasing solvent.)

2. Inspect generator drive end frame bearings for roughness or scored races
3. Inspect generator brush holders to see if they are bent or deformed; check generator brush springs for proper spring tension
4. Check fit of armature shaft in bushing in commutator end frame

   (NOTE: If bushing is excessively worn, the end frame should be replaced.)

5. Inspect armature commutator for roughness or out-of-round

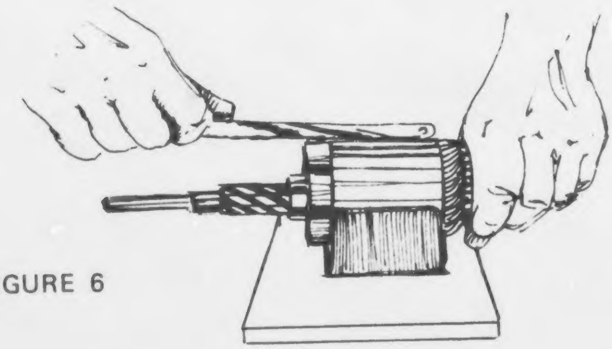
   (NOTE: If armature commutator is rough or out-of-round, it should be turned or serviced on an armature turning lathe.)

6. Test armature for shorts (Figure 6)
   - a. Place the armature on a growler and turn on
   - b. Rotate the armature while holding a hacksaw blade over the armature core

     (NOTE: If the blade vibrates, the armature is shorted and will require replacement.)

JOB SHEET #3

FIGURE 6



ARMATURE TEST FOR SHORTS

7. Test armature for ground (Figure 7)

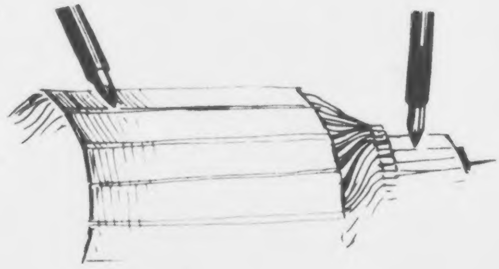
   a. Place one lead of a test lamp on the armature core or shaft

   b. Touch second lead to the commutator segments on the commutator

   c. Rotate the lead around the commutator, being certain to touch all segments

(NOTE: If the lamp lights, the armature is grounded and will require replacement.)

FIGURE 7



ARMATURE TEST FOR GROUND

8. Test armature for open

   a. Place one lead on a commutator segment

JOB SHEET #3

b. Place the other lead on the segment common with it

(NOTE: On a two brush generator they will be 180° apart, on a three brush they'll be 120° apart. The light should burn between these common segments.

c. Proceed around commutator until all segments have been checked

9. Test field coil for open circuit (Figure 8)

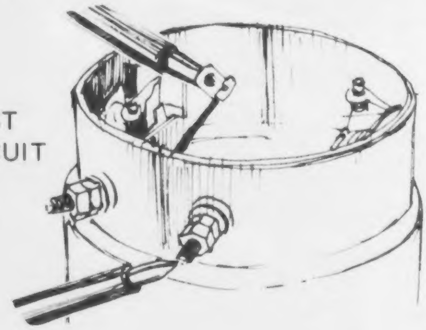
a. Place one lead of a test lamp on field terminal

b. Place the other lead on the end of the field coil lead through the armature terminal

(NOTE: If lamp does not light, the fields are open and must be replaced.)

FIGURE 8

FIELD COIL TEST
FOR OPEN CIRCUIT



10. Test field coil for ground ("A" circuit only) (Figure 9)

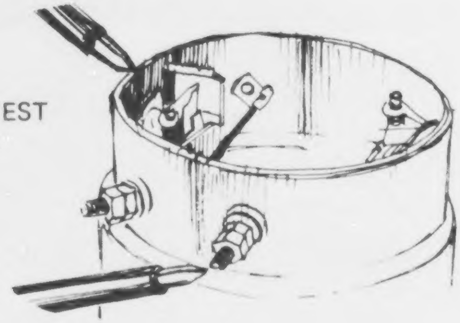
a. Place one lead of a test lamp on generator housing

b. Place the other lead on field terminal

(NOTE: If lamp lights, the field coils are grounded and must be repaired or replaced.)

FIGURE 9

FIELD COIL TEST
FOR GROUND



JOB SHEET #3

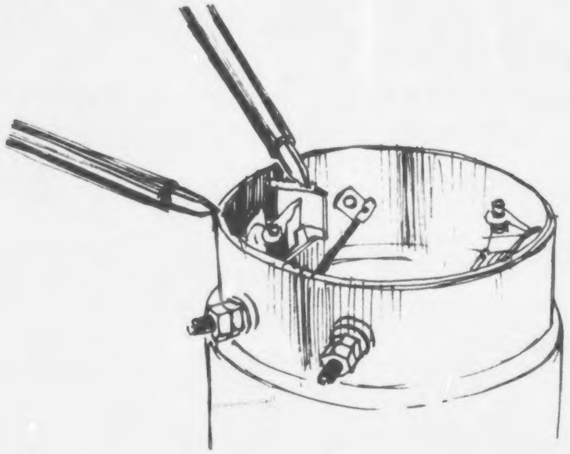
11. Check insulated brush holder for ground (Figure 10)

    a. Place one lead of a test lamp on brush holder

    b. Place the other lead on the generator housing

    (NOTE: If lamp lights, insulated brush is grounded and must be repaired.)

FIGURE 10



INSULATED BRUSH HOLDER TEST FOR GROUND

12. Inspect all parts for wear or damage

13. Replace all damaged or worn parts

C. Reassemble generator

1. Pack the generator ball bearings with high melting point ball bearing grease

2. Install the ball bearing in the drive end frame

   (NOTE: Make sure gasket is in place and retainer screws tightened securely.)

3. Install the drive end frame and bearing assembly onto armature shaft

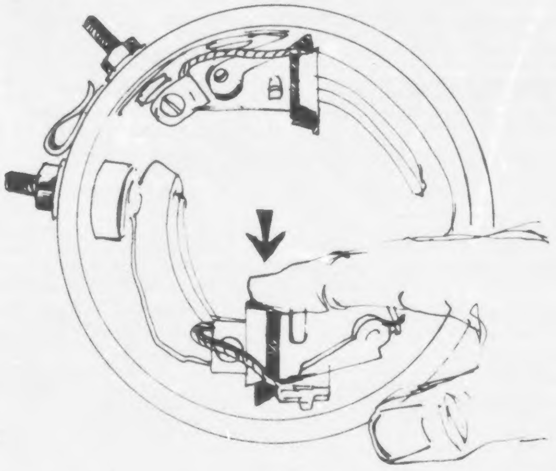
   (NOTE: Make sure ball bearing spacers are in place if used.)

JOB SHEET #3

4. Install ball bearing spacers, fan, pulley, and retaining nut
5. Tighten retaining nut securely
6. Install new brushes in brush holders and push brushes back against spring tension (Figure 11)

   (NOTE: If brushes are over 1/2 of original length they can be reused.)

FIGURE 11



PUSH BRUSHES BACK AGAINST SPRING

7. Install armature and drive end frame assembly into generator housing
8. Release brushes so they will contact commutator
9. Assemble commutator end frame over end of armature shaft
10. Rotate both end frames until dowels engage, then start thru bolts
11. Tighten thru bolts securely
12. Check generator operation before replacing on vehicle

GENERATOR CHARGING CIRCUITS
UNIT VII

JOB SHEET #4--TEST AND ADJUST A REGULATOR UNIT

I. Tools and materials

- A. Vehicle
- B. Basic hand tool set
- C. Air gap gauge
- D. Riffler file or crocus cloth
- E. 1/4 ohm fixed resistor
- F. Voltmeter
- G. Ammeter
- H. Variable resistor
- I. Safety glasses
- J. Appropriate service manual

II. Procedure

(CAUTION: Remove all jewelry prior to working on any electrical system and follow all shop safety procedures.)

A. Test and adjust voltage regulator

1. Measure air gap

   a. Push down on the armature until points are just touching

   b. Measure the gap between the armature and the core with proper size gauge as specified by the technical manual

   c. Adjust gap as specified by technical manual (Figure 1)

   (NOTE: On some regulators, a screw post at the top of the unit is adjusted to lengthen or shorten the distance.) (Figure 1)

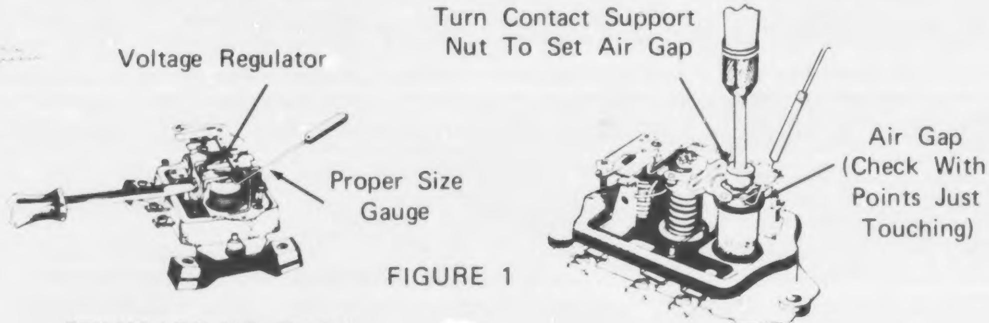

Voltage Regulator
Proper Size Gauge
Turn Contact Support Nut To Set Air Gap
Air Gap (Check With Points Just Touching)

FIGURE 1

STANDARD VOLTAGE REGULATOR

POST-TYPE VOLTAGE REGULATOR

JOB SHEET #4

2. Test voltage setting

   a. Test using fixed resistance method

      1) Insert a 1/4 ohm fixed resistor into the charging circuit at the battery terminal (Figure 2)

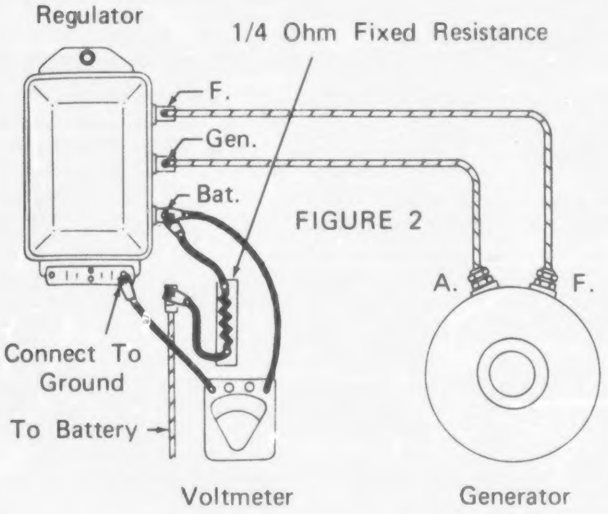

Regulator
1/4 Ohm Fixed Resistance
F.
Gen.
Bat.
A.
F.
Connect To Ground
To Battery
Voltmeter
Generator

FIGURE 2

FIXED RESISTANCE METHOD

      2) Connect a voltmeter from the battery terminal to ground

      3) Operate the circuit for 15 minutes at specified speed to warm it up

      4) Cycle the generator by one of two methods:

         a) Slow it down until voltage drops to about 1/4 of rated value

         b) Cycle the generator by inserting a variable resistance into the field circuit

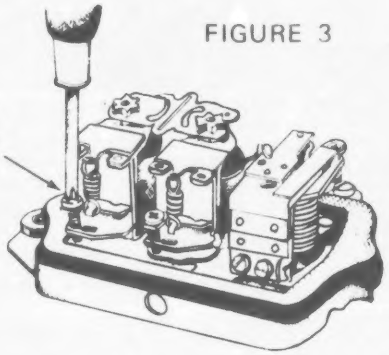
      5) Increase resistance slowly until voltage drops to about 1/4 of rated value

      6) Decrease the resistance and note the voltage reading

JOB SHEET #4

7) Adjust the voltage setting by turning the adjusting screw (Figure 3)

FIGURE 3



VOLTAGE SETTING ADJUSTMENT

(NOTE: If the adjusting screw is turned to its limits, it may be necessary to bend the spring support; however, do this very carefully.)

8) Make final adjustment by increasing the spring tension

(NOTE: If the setting is too high, adjust the unit below the specified value and then bring it back to this value by increasing the spring tension.)

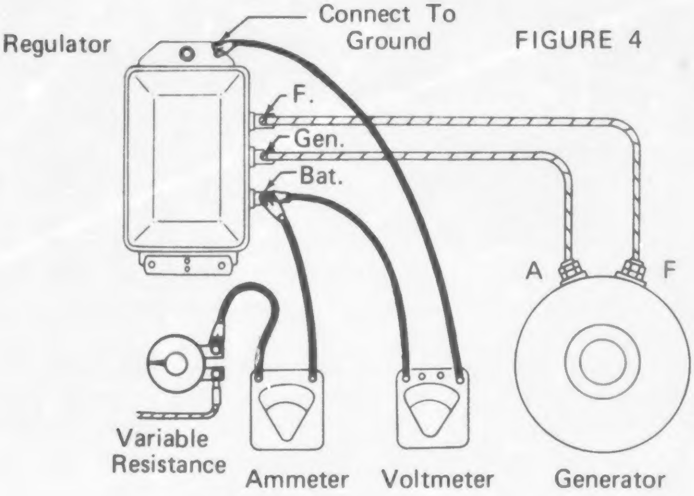
9) Replace the cover and cycle the generator after each adjustment and before taking a reading

b. Test using variable resistance method

1) Connect a variable resistor and an ammeter into the charging circuit at the battery terminal (Figure 4)

JOB SHEET #4

FIGURE 4


Regulator
Connect To Ground
F.
Gen.
Bat.
A
F
Variable Resistance
Ammeter
Voltmeter
Generator

VARIABLE RESISTANCE METHOD

Checking The Voltage Setting Of Voltage Regulator

2) Connect a voltmeter from the battery terminal to ground

3) Start generator and adjust resistor to get a current flow of not more than 10 amperes

4) Operate the generator at specified speed to warm it up

5) Cycle the generator as in a4) above

6) Adjust the voltage as in a5) above

B. Test and adjust cut-out relay

1. Check air gap

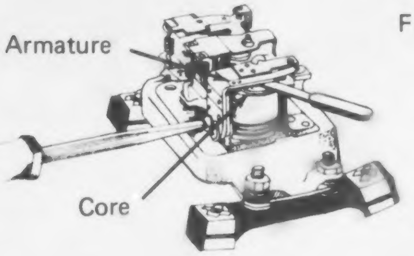
a. Disconnect battery from regulator

b. Push the cut-out armature down until the points are just touching

JOB SHEET #4

c. Measure the air gap between the armature and the center of the core using a feeler gauge (Figure 5)

FIGURE 5


Armature
Core

AIR GAP ADJUSTMENT OF CUT-OUT RELAY

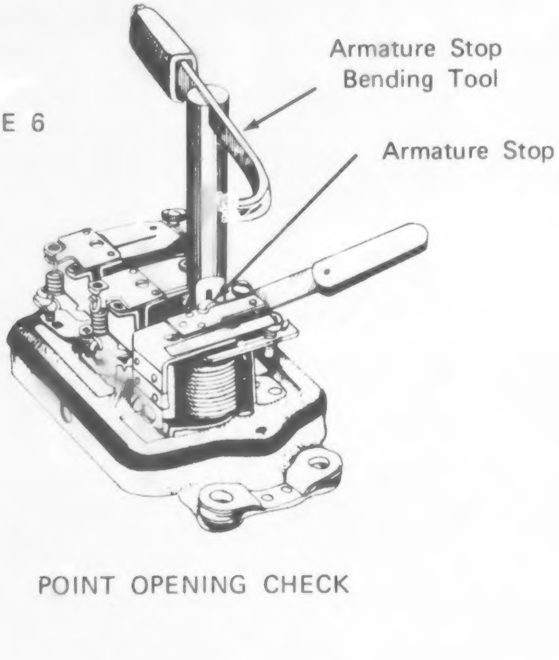
d. Adjust the air gap

e. Raise or lower the armature as needed and make sure the points are aligned

f. Tighten the screws after adjustment

2. Check point opening and adjust by bending the armature stop with a tool (Figure 6)

FIGURE 6


Armature Stop
Bending Tool
Armature Stop

POINT OPENING CHECK

JOB SHEET #4

3. Check closing voltage

   a. Connect voltmeter between the generator terminal and ground (Figure 7)

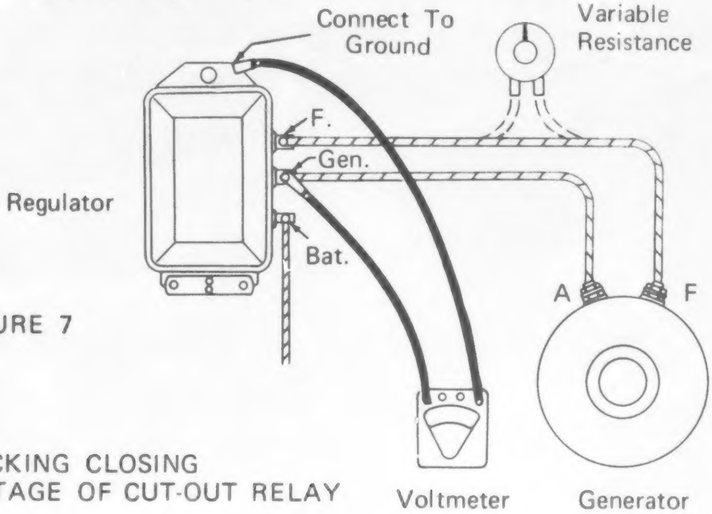

Connect To Ground
Variable Resistance
F.
Gen.
Regulator
Bat.
A
F
Voltmeter
Generator

FIGURE 7

CHECKING CLOSING
VOLTAGE OF CUT-OUT RELAY

   b. Increase the generator speed slowly and note the relay closing voltage

   c. Decrease the speed and make sure the points open before specified current flow is exceeded (with the battery connected)

JOB SHEET #4

d. Adjust the closing voltage (Figure 8)

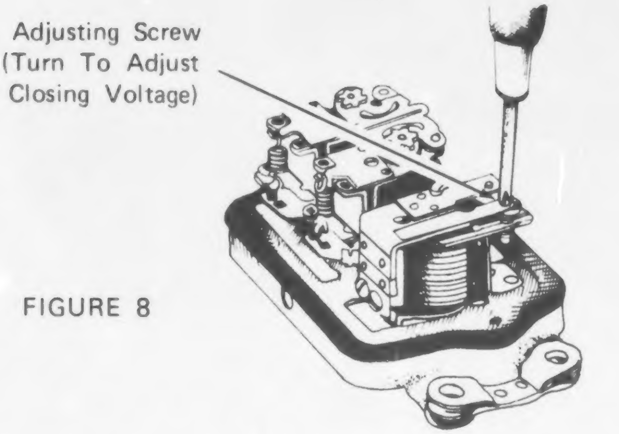

Adjusting Screw
(Turn To Adjust
Closing Voltage)

FIGURE 8

ADJUSTING CLOSING VOLTAGE OF CUT-OUT RELAY

e. Turn the screw clockwise to increase setting

C. Test current regulator

1. Test and adjust air gap as in B.1., voltage regulator above

2. Check current setting

(NOTE: Most current regulators have a temperature compensation. For these units, make the following test by the "load method.")

a. Connect an ammeter into the charging circuit (Figure 9)

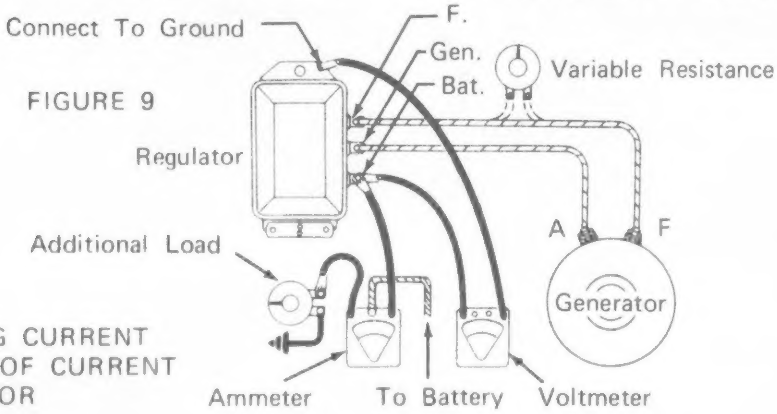

Connect To Ground
F.
Gen.
Bat.
Variable Resistance
Regulator
A
F
Additional Load
Generator
Ammeter
To Battery
Voltmeter

FIGURE 9

CHECKING CURRENT SETTING OF CURRENT REGULATOR

JOB SHEET #4

b. Turn on all accessories and connect an additional load across the battery (such as a bank of lights) to drop the system voltage about 1 volt below the voltage regulator setting

c. Operate the generator at specified speed to warm it up

d. Cycle the generator and note the current setting

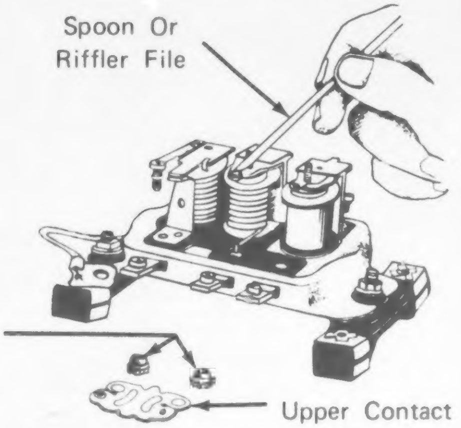
e. Adjust the setting in the same way as for voltage setting (Figure 3)

(NOTE: Before slowing down the generator, be sure to remove the extra load. This will prevent overloading of the wiring.)

D. Clean contact points

1. Remove upper contact support (Figure 10)

FIGURE 10



CLEANING THE REGULATOR CONTACT POINTS

2. Clean the points with a riffler file or crocus cloth and then wash

(NOTE: Never use emery cloth or sandpaper to clean the contact points; however, No. 400 grit silicone carbide paper or cloth may be used.)

GENERATOR CHARGING CIRCUITS
UNIT VII

NAME ______________________________

TEST

1. Match the terms on the right with their correct definitions.

______ a. Series of wire conductors in the form of a loop, rotating in a stationary magnetic field

______ b. Bars on end of armature drive shaft and connected to the ends of each wire conductor

______ c. Permanent magnets that are fixed to the inside of generator housing, and set opposite each other to create a weak magnetic field

______ d. One wire conductor wound around both poles many times and attached to the brush

______ e. An assembly which houses the cut-out relay, voltage regulator, and current regulator

______ f. Current attempting to cross between the commutator sections and the brush

______ g. Direction of current flow through the generator

______ h. Circuit in which a wire is broken or disconnected

______ i. Wire touching another wire and providing a shorter path for current to flow

______ j. Circuit in which a wire touches ground causing the current to flow to ground instead of through the circuit

1. Arcing
2. Pole shoes
3. Field circuit
4. Regulator
5. Armature
6. Commutator
7. Polarity
8. Open circuit
9. Grounded circuit
10. Short circuit

2. State the purpose of a generator charging circuit.

____

____

____

3. Name two kinds of charging circuits.

a. ______________________________

b. ______________________________

4. Match the names of the components in the DC charging circuit on the right with their correct functions.

_____a. Starts the circuit by supplying spark to start engine

_____b. Measures the rate of current flow

_____c. Supplies electrical power to accessory circuits

_____d. Prevents overcharging of battery (voltage regulator)

_____e. Opens and closes the charging circuit (cut-out relay)

_____f. Indicates produced voltage

_____g. Limits the generator's output to safe rates (current regulator)

_____h. Helps out during peak operation when electrical loads are too much for generator or alternator

_____i. Recharges battery

1. Ammeter
2. Generator
3. Regulator
4. Battery
5. Voltmeter

5. Identify the major parts of a generator.

a. ______________________

b. ______________________

c. ______________________

d. ______________________

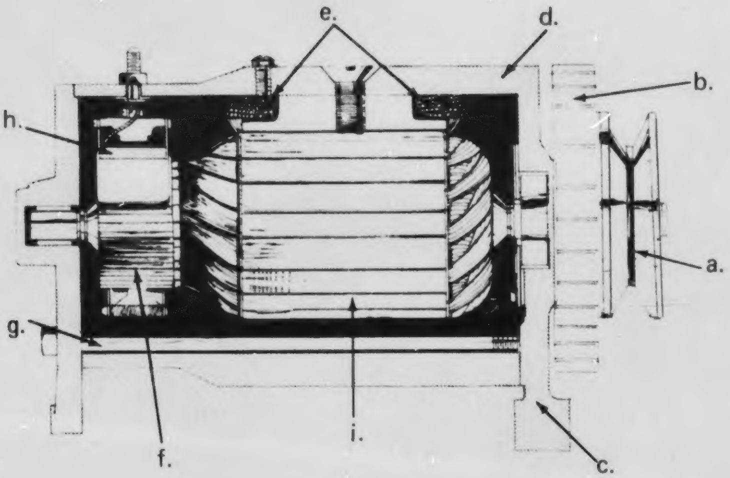
e. ______________________

f. ______________________

g. ______________________

h. ______________________

i. ______________________



6. Select true statements concerning the three operating stages of a charging circuit by placing an "X" in the appropriate blanks.

______a. Starting--Generator supplies all load current

______b. Peak operation--Generator helps battery supply current

______c. Normal operation--Generator supplies all current and recharges battery

7. Arrange in order the steps in which current flows in a basic generator by placing the correct sequence number in the appropriate blank.

______a. Current flows when circuit is complete

______b. Current flows from armature loop to the commutator ring

______c. Current flows from the commutator ring through brushes to a wire connected to a load

8. Explain how a field circuit is created in a generator.

____

____

9. Complete the following list of statements concerning how a generator converts AC to DC current.

   a. The commutator is split in two parts creating a gap as the commutator passes the brushes

   b. Past this point the other half of the commutator ______________________________

   ____

   c. At the same time the rotating armature ______________________________

   ____

10. Distinguish between an "A" generator field circuit and a "B" generator circuit by placing an "X" next to the description of an "A" generator field circuit.

    ______a. Current flows from the regulator through the field coils to ground

    ______b. Current flows from the armature circuit through the field to the regulator, then to ground

11. Match the names of the generator regulator components on the right with their correct functions.

    ______a. An automatic switch which closes when generator is running for battery charging and opens when generator stops to prevent battery discharge

    ______b. Controls the amount of voltage the regulator produces through a shunt coil and contact points controlling the strength of the magnetic field; prevents overheating

    ______c. Controls the current flow similar to the voltage regulator

    1. Voltage regulator
    2. Current regulator
    3. Cut-out relay

12. Match the types of generators on the right with their uses.

    ______a. Used as a standard generator for most normal operations

    ______b. Eliminates the use of a current regulator, is relatively easy to change third brush position and control the output, and is used in systems with low speed and low load requirements

    ______c. Provides a better commutation point and extends brush life

    ______d. Used where there is a wide variation of load and speed requirements

    ______e. Used in systems with low speed, but high load requirements

    1. Split field
    2. Interpole
    3. Third brush
    4. Shunt
    5. Bucking field

13. Match the types of electrical failure on the right with their causes.

______a. Unwanted connections, usually copper-to-copper, that allow current to bypass all or part of the circuit

______b. Breaks in the circuit which cause extremely high resistance

______c. Unwanted connections that bypass all or part of the circuit from the insulated side to the grounded side

______d. Usually caused by poor or corroded connections and frayed or damaged wires, creating greater resistance in the circuit

1. Open circuits
2. Grounded circuits
3. High resistance circuits
4. Short circuits

14. Select true statements concerning reverse polarity by placing an "X" in the appropriate blanks.

______a. Generator polarity is opposite that of the battery

______b. Battery is in series with the generator

______c. Battery builds up voltage and closes the cut-out relay points

______d. High voltage can create enough current and heat to weld the points together

15. Demonstrate the ability to:

a. Test generator output.

b. Remove and replace a generator.

c. Disassemble, test, and reassemble a generator.

d. Test and adjust a regulator unit.

(NOTE: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

GENERATOR CHARGING CIRCUITS
UNIT VII

ANSWERS TO TEST

1. a. 5
   b. 6
   c. 2
   d. 3
   e. 4
   f. 1
   g. 7
   h. 8
   i. 10
   j. 9

2. The generator charging circuit recharges the battery and generates current during operation of the engine

3. a. Direct current
   b. Alternating current

4. a. 4
   b. 1
   c. 2
   d. 3
   e. 3
   f. 5
   g. 3
   h. 4
   i. 2

5. a. Pulley
   b. Fan
   c. Drive end frame
   d. Generator housing
   e. Field coils
   f. Commutator
   g. Thru bolts
   h. Brushes
   i. Armature

6. c

7. a. 3
   b. 1
   c. 2

8. Wire conductors are wound around the magnets (magnetic poles) and connected to the brushes to strengthen the field

9. b. Contacts the brushes reversing the current flow
   c. Reverses its polarity converting AC to DC

10. b

11. a. 3
    b. 1
    c. 2

12. a. 4
    b. 3
    c. 2
    d. 5
    e. 1

13. a. 4
    b. 1
    c. 2
    d. 3

14. a, b, d

15. Performance skills evaluated to the satisfaction of the instructor

ALTERNATOR CHARGING CIRCUITS
UNIT VIII

UNIT OBJECTIVE

After completion of this unit, the student should be able to identify the components of an alternator, match the components with their correct functions, and distinguish between an alternator and a generator. The student should also be able to disassemble, test, and reassemble an alternator. This knowledge will be evidenced by correctly performing the procedures outlined in the job sheets and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to alternator charging circuits with their correct definitions.
2. State the purpose of the alternator charging circuit.
3. Match the names of the alternator charging circuit components with their correct functions.
4. Identify the major parts of an alternator.
5. Distinguish between an alternator and a generator.
6. List two advantages of an alternator as opposed to a generator.
7. Explain why an alternator produces more current at low speed than a generator.
8. Discuss the construction of stator windings.
9. Discuss how an alternator is controlled by a regulator.
10. Select true statements concerning brushless alternators.
11. Select true statements concerning the operation of a brushless alternator.
12. Match the component parts of a transistorized regulator with their correct functions.
13. Select true statements concerning the operation of a transistorized regulator.
14. List safety rules for working with alternator charging circuits.
15. Demonstrate the ability to:
    a. Test the alternator charging circuit and regulator.

b. Remove and replace an alternator.

c. Disassemble, test, and reassemble an alternator.

d. Test and repair a transistorized regulator.

e. Test an alternator with an I.C. regulator.

ALTERNATOR CHARGING CIRCUITS
UNIT VIII

SUGGESTED ACTIVITIES

I. Provide student with objective sheet.

II. Provide student with information and job sheets.

III. Make transparencies.

IV. Discuss unit and specific objectives.

V. Discuss information sheet.

VI. Demonstrate and discuss the procedures outlined in the job sheets.

VII. Demonstrate diode removal procedure.

VIII. Disassemble a brushless alternator.

IX. Review safety precautions on electrical systems.

X. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:
  A. Objective sheet
  B. Information sheet
  C. Transparency masters
    1. TM 1--Alternator Charging Circuit Components
    2. TM 2--Alternator Circuit Schematic
    3. TM 3--Parts of an Alternator
    4. TM 4--Parts of an Alternator (Continued)
    5. TM 5--Differences Between an Alternator and Generator
    6. TM 6--Stator Winding Construction
    7. TM 7--Brushless Alternator Construction
    8. TM 8--Brushless Alternator Schematic

D. Job sheets

  1. Job Sheet #1--Test the Alternator Charging Circuit and Regulator

  2. Job Sheet #2--Remove and Replace an Alternator

  3. Job Sheet #3--Disassemble, Test, and Reassemble an Alternator

  4. Job Sheet #4--Test and Repair a Transistorized Regulator

  5. Job Sheet #5--Test an Alternator with an I.C. Regulator

E. Test

F. Answers to test

II. References:

A. *Fundamentals of Service: Electrical Systems*. Fourth Edition. Moline, IL: Deere and Company, 1979.

B. Stockel, Martin W. *Auto Service and Repair*. Homewood, IL: Goodheart-Willcox Company, 1969.

C. Billiet, Walter E., and Leslie F. Goings. *Automotive Electrical Systems*. Third Edition. Chicago,: American Technical Society, 1970.

D. Toboldt, William K., and Puruis, Jud. *Motor Services Automotive Encyclopedia*. Homewood, IL: Goodheart-Willcox Company, 1965.

E. Dagel, John F. *Diesel Engine Repair*. New York: John Wiley and Sons, Inc., 1982.

F. Foutes, William A. *Diesel Engine Mechanics*. Stillwater, OK: Mid-America Vocational Curriculum Consortium, 1977.

ALTERNATOR CHARGING CIRCUITS
UNIT VIII

INFORMATION SHEET

I. Terms and definitions

A. Rotor--Wire coil wrapped around an iron core and mounted on a rotating shaft

(NOTE: The rotor assembly does the same job for the alternator as the field coil and pole shoe do for the generator; however, the rotor assembly revolves.)

B. Stator--Laminated soft iron ring with three groups of coils

(NOTE: The stator assembly does the same job as the armature in a generator; however, the stator is fixed while the armature turns.)

C. Diode--Device that allows current to flow in one direction and blocks current in opposite direction

D. Slip rings--Metal conductors in the form of a ring, fastened to each end of coil and mounted on rotor shaft

(NOTE: Current flows through the regulator, through the insulated brush, through one slip ring into the coil, and out through the other slip ring and the other brush to ground.)

E. Short circuit--Wire touching another wire and providing a shorter path for current to flow

F. Open circuit--Circuit in which a wire is broken or disconnected

G. Grounded circuit--Circuit in which a wire touches ground causing the current to flow to ground instead of through the circuit

H. Transistorized regulator--Fully electronic unit composed of resistors, diodes, zener diode, transistors, and thermistor

I. Heat sink--Dissipates heat from diodes

(NOTE: High ampere alternators often use finned diodes for better heat removal.)

J. Brushless alternator--An alternator that has neither slip rings nor brushes (Transparency 7)

(NOTE: Some brushless alternators are sealed units cooled by engine oil.)

K. Potentiometer--Acts as a voltage divider or voltage adjustment

II. Purpose of the alternator charging circuit--The alternator charging circuit recharges the battery and maintains a supply of electrical current to meet the operating needs of the equipment

INFORMATION SHEET

III. Alternator charging circuit components and functions (Transparencies 1 and 2)

   A. Battery

      1. Starts the circuit by supplying spark to start engine

      2. Helps out during peak operation when electrical load is too much for alternator

      3. Stabilizes system voltage

   B. Alternator

      1. Supplies electrical power to accessory circuits

      2. Recharges battery

   C. Regulator--Limits the alternator voltage to a safe, preset value

   D. Ammeter--Measures the rate of current flow

   E. Voltmeter--Indicates produced voltage

   F. Indicator lights--Indicates problems in system; used in place of a meter

IV. Major parts of an alternator (Transparencies 3 and 4)

   A. Drive end frame

   B. Rotor assembly

   C. Stator assembly

   D. Slip ring end frame

   E. Diodes

   F. Brush assembly

   G. Pulley

V. Differences between an alternator and generator (Transparency 5)

   A. Alternator

      1. Rotates the field inside the stationary windings

      2. Rectifies the AC current to DC with a series of diodes

   B. Generator

      1. Rotates the windings (armature) inside the field

      2. Rectifies AC current to DC through the use of a segmented commutator and brushes

INFORMATION SHEET

VI. Advantages of an alternator as opposed to a generator

- A. Produces higher output at lower engine speeds
- B. Simplicity in construction requires less maintenance and space

VII. Why alternator produces more current at low speed than a generator--Alternator has more pole pieces than the generator so that many more magnetic lines of force are cut during one revolution of the rotor

(NOTE: The alternator usually has fourteen pole pieces and the generator usually has two.)

VIII. Construction of stator windings--Windings have three phases or groups of windings, with each winding connected to a positive and negative diode (Transparency 6)

IX. Control of alternator by regulator--Regulator places a resistance in the field circuit which reduces current flow to the alternator rotor

(NOTE: No current regulator is needed, since the alternator limits its output by setting its own opposing field during operation.)

X. Brushless alternator (Transparency 7)

- A. High mileage unit
- B. Used on both gasoline and diesel engines
- C. Regulator compartment can be vented for increased capability
- D. Uses large bearings at both ends
- E. Has extra large grease reservoirs
- F. Has extra large lip seal to keep grease in and dirt out
- G. Regulator compartment is air tight
- H. Designed to operate between engine overhauls without attention

XI. Operation of a brushless alternator (Transparency 8)

- A. To generate voltage in the stator windings, it is only necessary for the rotor to cause alternating north and south magnetic lines to cut across the stator windings
- B. The field coil is mounted to the end frame
- C. The rotor is mounted on bearings and fits between the stator and field coil
- D. The field coil produces a north pole at the right hand side of the coil

INFORMATION SHEET

E. Magnetic lines cross the air gap between the field coil and rotor to make all the right hand rotor poles all north poles

F. The non-magnetic lines of force cannot go through the non-magnetic ring directly; instead they pass through the air gap into the left hand south magnetic poles of the rotor; the magnetic lines then cross the air gap between the rotor and field coil and then into the field coil to complete the magnetic path

G. The non-magnetic ring has diverted the magnetic field into the stator windings, and as the rotor turns, AC voltage is generated in the stator windings

XII. Component parts of a transistorized regulator and functions

A. Resistors--Devices made of wire or carbon which produce a resistance to current flow

B. Zener diode--Diode connected in a reverse bias, which will conduct a reverse current beyond a predetermined voltage

C. Transistor--Semiconductors which control the flow of current by either allowing it to flow or stopping it

D. Thermistor--Temperature-compensated resistor whose degree of resistance varies with the temperature

(NOTE: It controls the zener diode so that a higher system voltage is produced in cold weather, when needed.)

XIII. Operation of a transistorized regulator

A. Allows battery current to excite the alternator field coils

B. Controls charging voltage at safe values during operation

XIV. Safety rules for working with alternator charging circuits

A. Never attempt to polarize the circuit

B. Be sure the battery is in good operating condition before making any tests or adjustments

C. Never operate the alternator in an open circuit, except when instructed in the technical manual

D. Never short or ground the alternator terminals

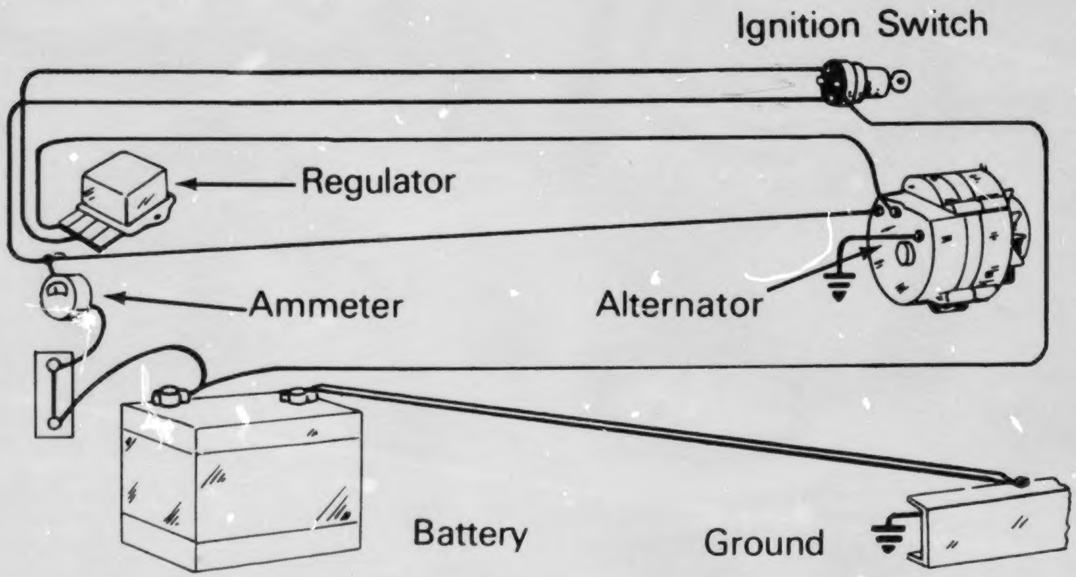
E. Do not disconnect the voltage regulator while the alternator is running

F. Disconnect the negative battery cable first when removing the alternator or battery

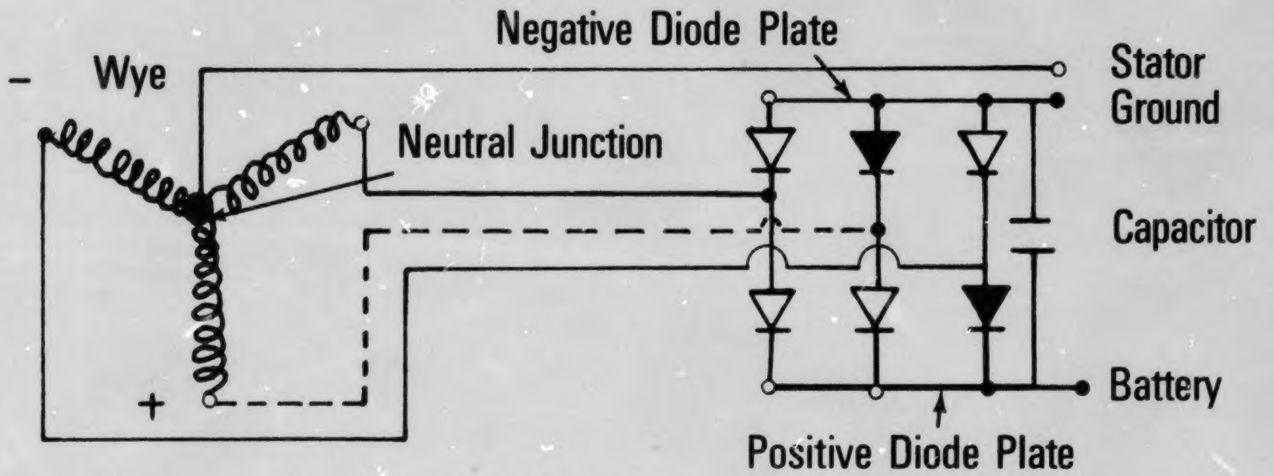
G. Do not use acid-core solder on the alternator terminals; use only a rosin-core solder

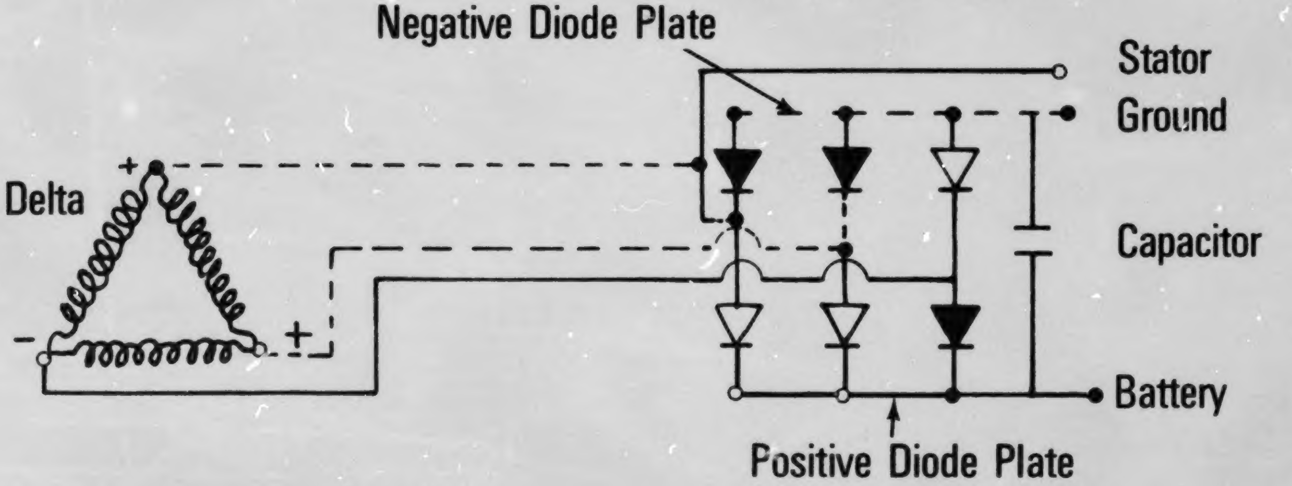
H. Never immerse the circuit components in cleaning solution

Alternator Charging Circuit Components

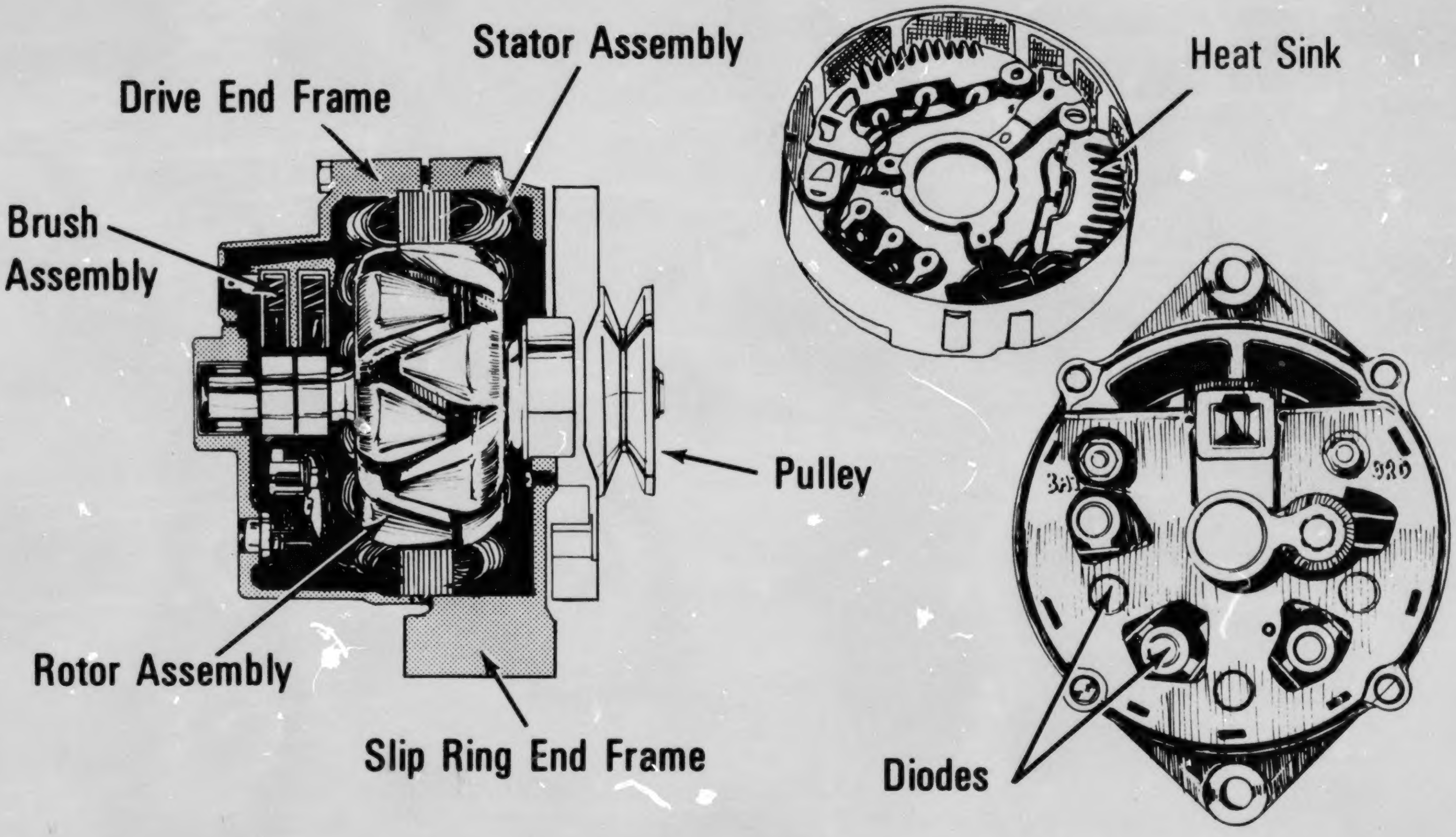

Ignition Switch
Regulator
Ammeter
Alternator
Battery
Ground

Alternator Circuit Schematic


Negative Diode Plate
–
Wye
Stator
Ground
Neutral Junction
Capacitor
+
Battery
Positive Diode Plate

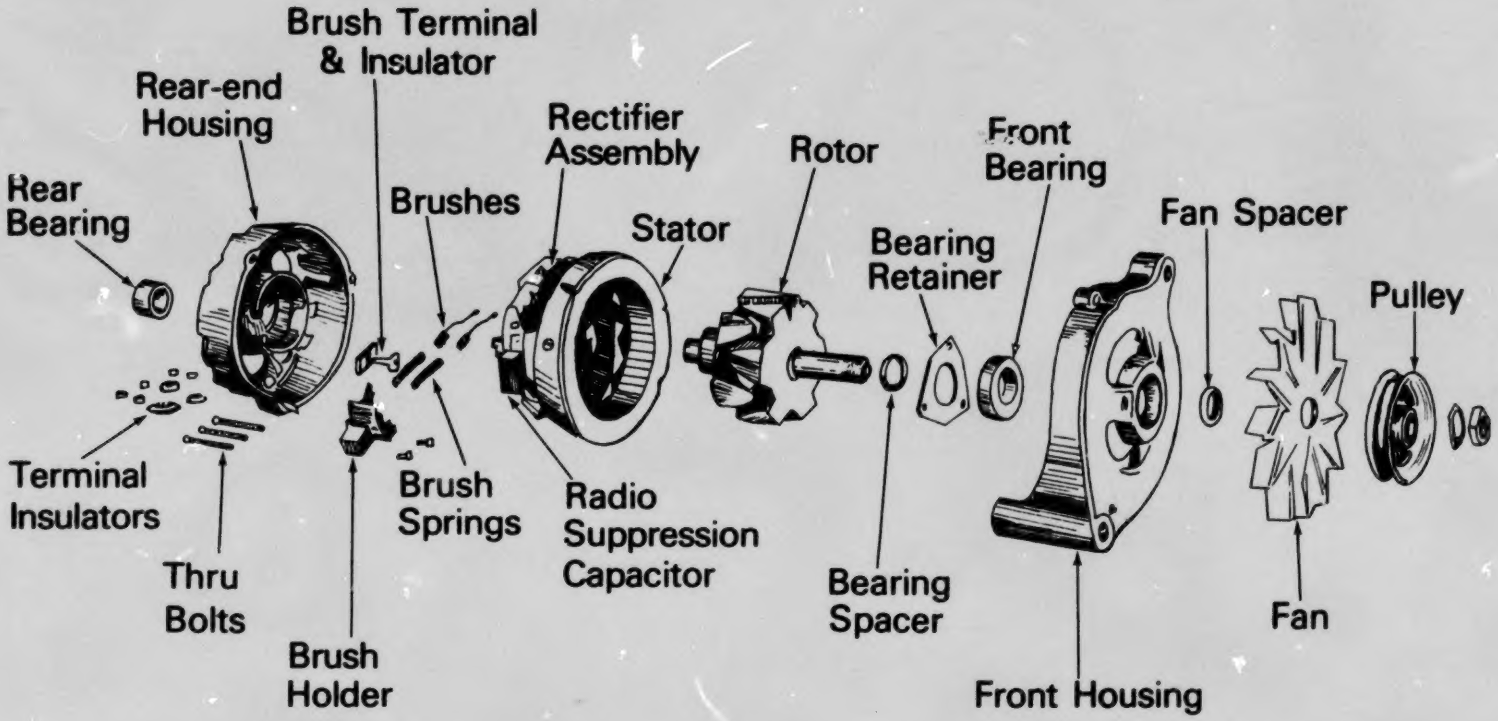

Negative Diode Plate
Stator
Ground
+
Delta
Capacitor
–
±
Battery
Positive Diode Plate

Parts of an Alternator

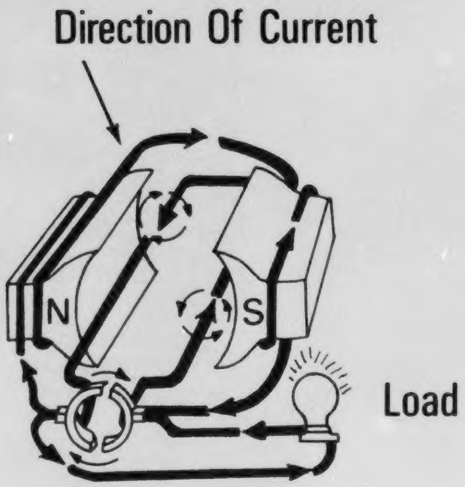

Stator Assembly
Drive End Frame
Brush Assembly
Rotor Assembly
Slip Ring End Frame
Pulley
Heat Sink
Diodes
BAT
GRD

Parts of an Alternator

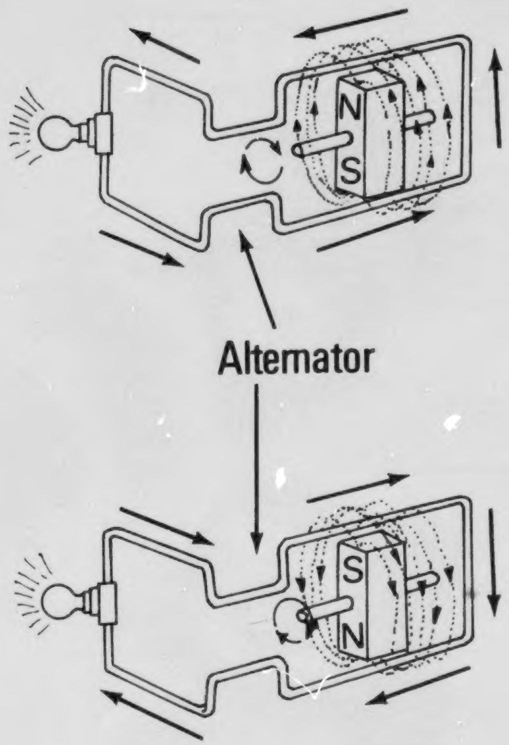
(Continued)


Brush Terminal & Insulator
Rear-end Housing
Rear Bearing
Brushes
Rectifier Assembly
Stator
Rotor
Front Bearing
Bearing Retainer
Fan Spacer
Pulley
Terminal Insulators
Thru Bolts
Brush Holder
Brush Springs
Radio Suppression Capacitor
Bearing Spacer
Front Housing
Fan

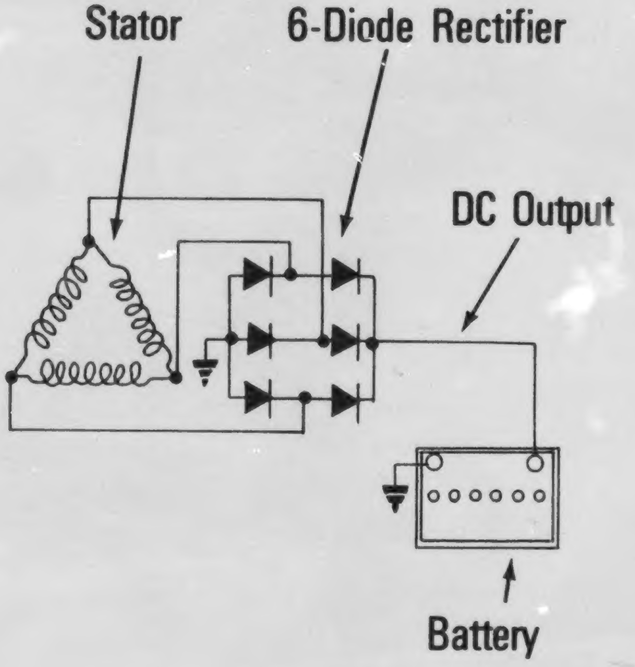
Differences Between an Alternator and Generator


Direction Of Current
N
S
Load

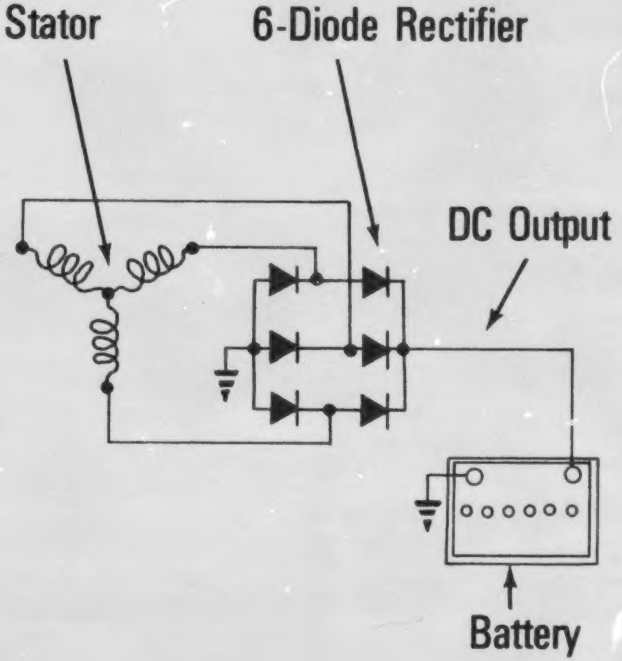
DC Generator


N
S
Alternator
S
N

Stator Winding Construction

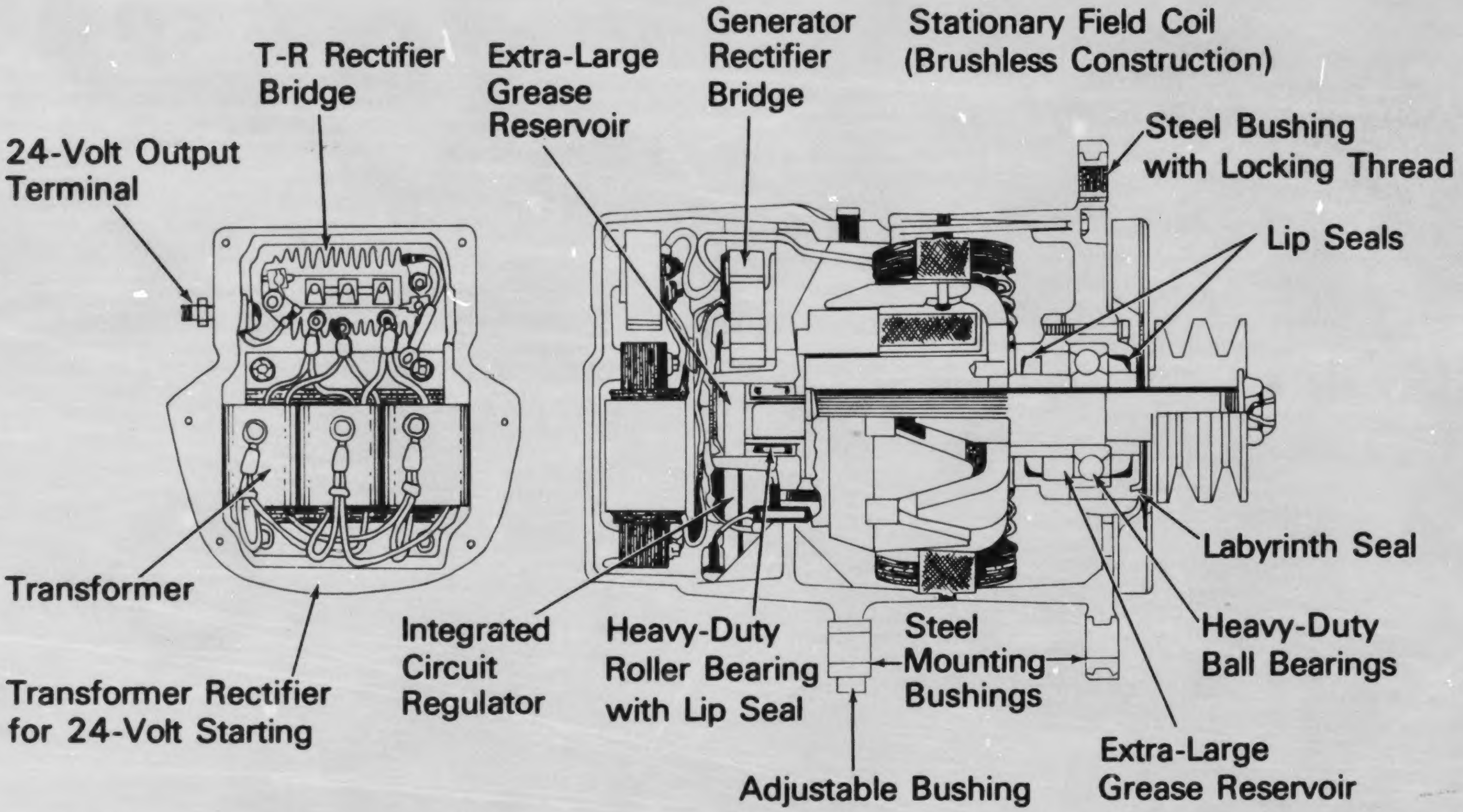

Stator
6-Diode Rectifier
DC Output
Battery

DELTA-CONNECTED STATOR WINDINGS

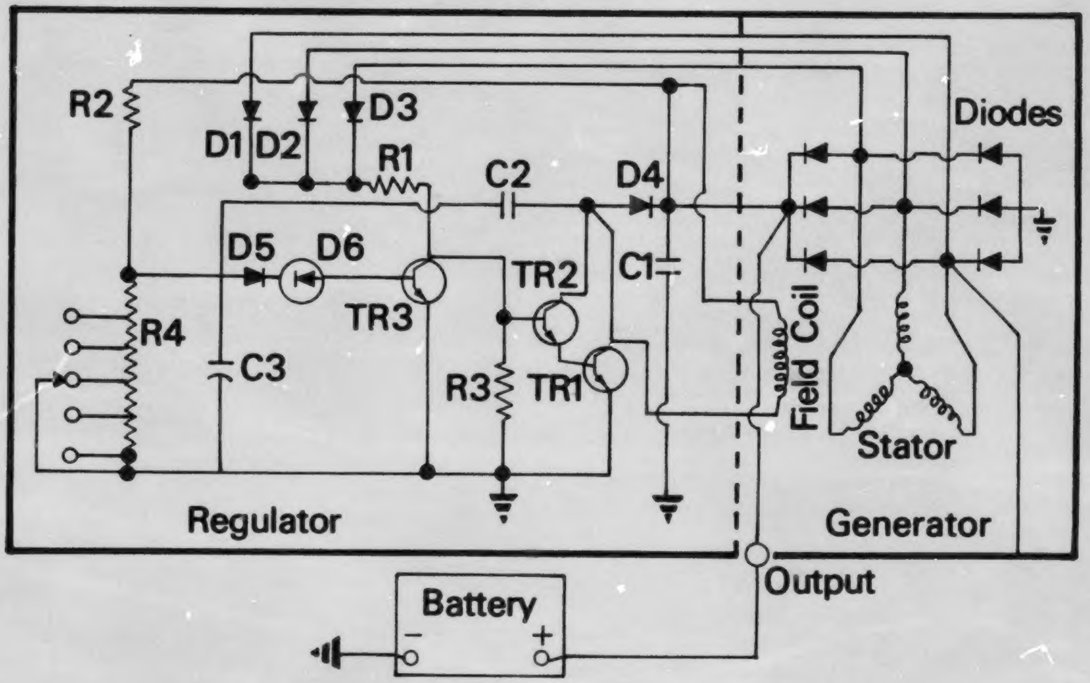

Stator
6-Diode Rectifier
DC Output
Battery

"Y"-CONNECTED STATOR WINDINGS

Brushless Alternator Construction


T-R Rectifier Bridge
Extra-Large Grease Reservoir
Generator Rectifier Bridge
Stationary Field Coil (Brushless Construction)
24-Volt Output Terminal
Steel Bushing with Locking Thread
Lip Seals
Labyrinth Seal
Transformer
Integrated Circuit Regulator
Heavy-Duty Roller Bearing with Lip Seal
Steel Mounting Bushings
Heavy-Duty Ball Bearings
Transformer Rectifier for 24-Volt Starting
Adjustable Bushing
Extra-Large Grease Reservoir

Brushless Alternator Schematic


R2
D1
D2
D3
R1
C2
D4
Diodes
D5
D6
TR2
C1
TR3
R4
C3
R3
TR1
Field Coil
Stator
Regulator
Generator
Output
Battery
−
+

316

317

ALTERNATOR CHARGING CIRCUITS
UNIT VIII

JOB SHEET #1--TEST THE ALTERNATOR CHARGING CIRCUIT AND REGULATOR

I. Tools and materials

- A. Vehicle
- B. Basic hand tool set
- C. Voltmeter
- D. Ammeter
- E. Variable resistor
- F. Jumper wire
- G. Safety glasses

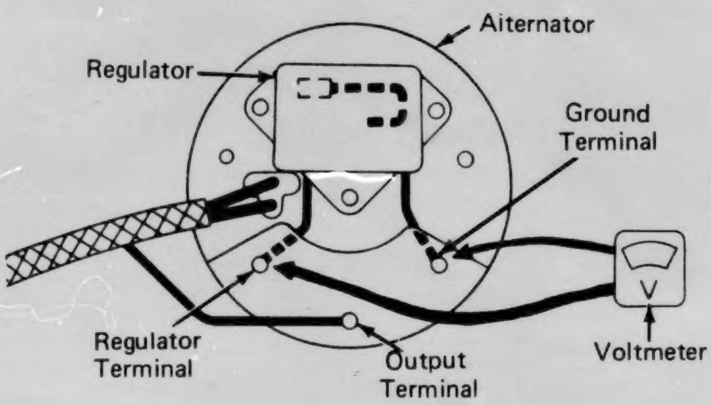
II. Procedure

(CAUTION: Remove all jewelry prior to working on electrical system and follow all shop safety procedures.)

A. Perform test no. 1

1. Connect the voltmeter across the regulator terminal and ground terminal (Figure 1)

FIGURE 1


Alternator
Regulator
Ground Terminal
V
Regulator Terminal
Output Terminal
Voltmeter

VOLTMETER TEST CONNECTIONS

JOB SHEET #1

2. With the engine, ignition key switch, and accessories off, the voltmeter should read less than 0.1 volt

   (NOTE: A high reading indicates a shorted isolation diode or ignition key switch.)

B. Perform test no. 2

1. Turn the ignition key switch on

   (NOTE: This test should be conducted under the same conditions as test no. 1.)

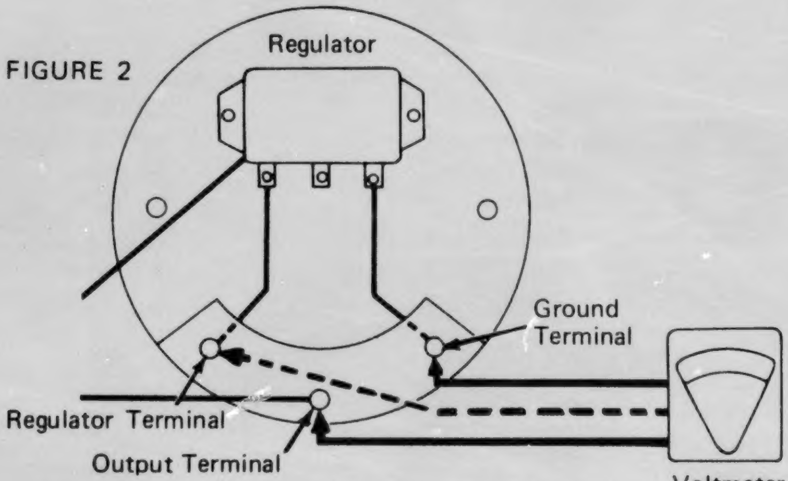
2. Read the voltmeter; it should be between 2 and 3 volts

   (NOTE: A high reading could be caused by a high resistance in the alternator field, defective brushes, or a defective regulator. A low reading might indicate a shorted alternator field, a defective regulator, or an open circuit.)

C. Perform test no. 3

1. Leave the voltmeter connected to the ground terminal and regulator terminal of the alternator (Figure 2)

FIGURE 2



VOLTMETER CONNECTIONS

2. Keep the engine running and the key switch on, but all accessories off; the voltmeter should read more than 15 volts

3. Move the voltmeter lead from the regulator terminal to the output terminal; the voltmeter should read 1 volt less

   (NOTE: If the regulator terminal voltage is correct and the output terminal is the same as battery voltage, then the isolation diode is open.)

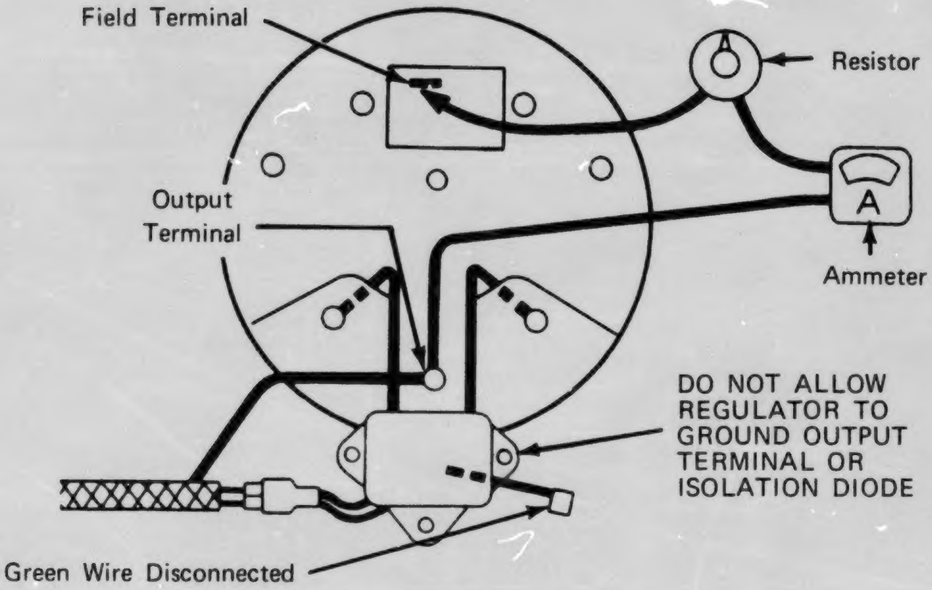
JOB SHEET #1

D. Perform test no. 4

(NOTE: This test is usually performed if test no. 2 indicated a malfunction.)

1. Turn the engine and switch off, then disconnect the regulator-to-alternator field terminal wire (Figure 3)

FIGURE 3


Field Terminal
Resistor
Output Terminal
Ammeter
A
DO NOT ALLOW REGULATOR TO GROUND OUTPUT TERMINAL OR ISOLATION DIODE
Green Wire Disconnected

AMMETER CONNECTIONS

(NOTE: Let the regulator hang on the wires connected to the regulator and ground alternator terminals. Be very careful in how the regulator hangs. Do not allow it to ground on the output terminal.)

2. Connect the ammeter in series with a variable resistor to the field terminal and output terminal

3. Read the ammeter; with all resistance eliminated, it should read 2.0 to 2.5 amps with the alternator cold

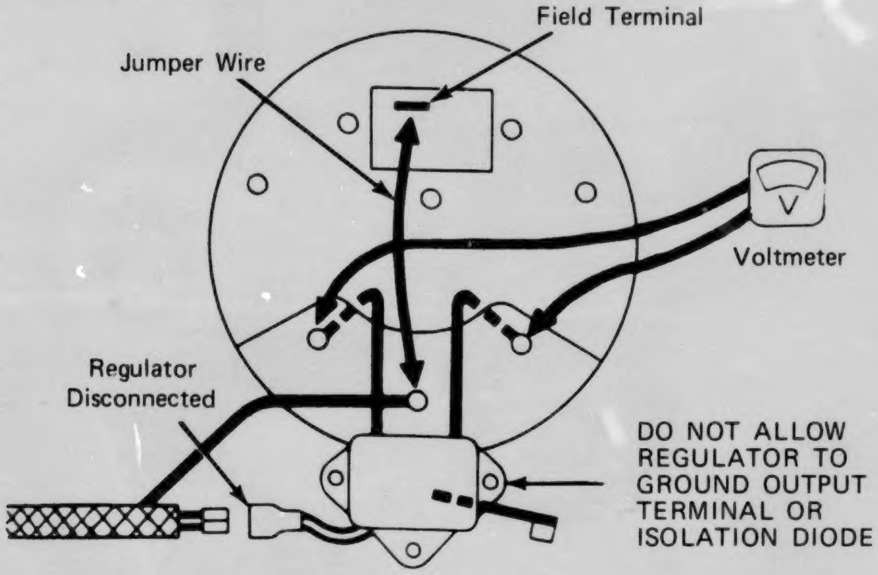
(NOTE: A high reading indicates a shorted field winding or brushes. A low reading means a high resistance in the brushes or slip ring, or an open circuit in the field windings.)

JOB SHEET #1

E. Perform test no. 5

1. Connect the voltmeter and jumper wire (Figure 4)

FIGURE 4


Field Terminal
Jumper Wire
Voltmeter
V
Regulator Disconnected
DO NOT ALLOW REGULATOR TO GROUND OUTPUT TERMINAL OR ISOLATION DIODE

JUMPER WIRE AND VOLTMETER CONNECTIONS

2. Run the engine at a specified speed

   Example: 800 rpm

3. Read the voltmeter; it should give a reading of 15 volts

   (CAUTION: Do not allow voltage to go above 16.5 volts.)

   (NOTE: If this test proved to be satisfacory, but test no. 3 voltage was below specifications, the regulator is probably at fault. If this test voltage was low, but tests no. 2 and 4 were satisfactory, the alternator is probably faulty.)

F. Test wiring resistance

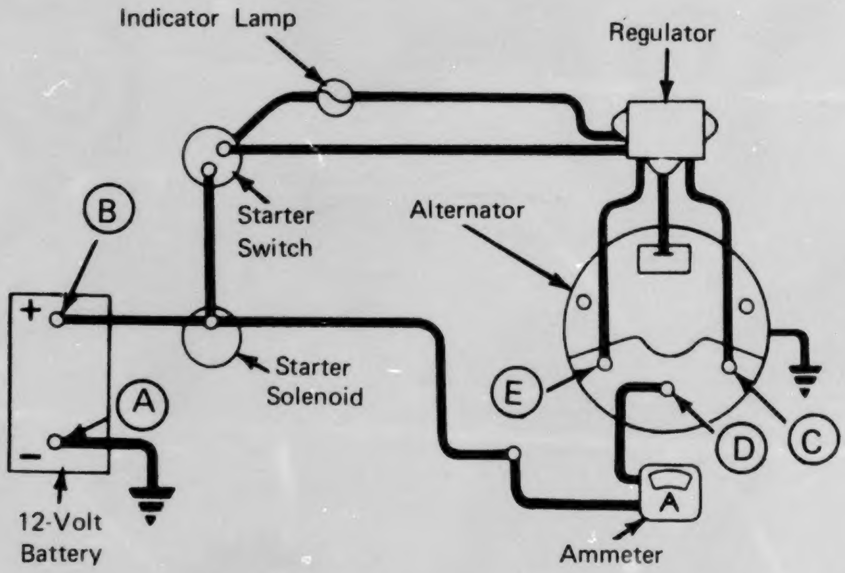
(NOTE: If the alternator and regulator operate properly, check the wiring.)

1. Make a quick visual check of the lead connections and wires

JOB SHEET #1

2. Disconnect battery ground cable, then disconnect alternator output wire and connect ammeter (Figure 5)

FIGURE 5


Indicator Lamp
Regulator
Starter Switch
Alternator
B
Starter Solenoid
A
E
D
C
12-Volt Battery
Ammeter
A
+
–

WIRING TEST POINTS

3. Connect ground cable and run engine to obtain a 10-amp charging rate

4. Check the voltage, with a voltmeter, at different points (Figure 2)

5. The voltage between these points should be as follows:

Test Points	Max. Voltage
A-C	0.3 volts
B-D	0.3 volts
B-E	1.3 volts

6. Disconnect battery ground cable to prevent accidental grounding while connecting the alternator output terminal wire

7. Reconnect battery ground cable

(NOTE: A high reading indicates a high resistance in the wiring or components.)

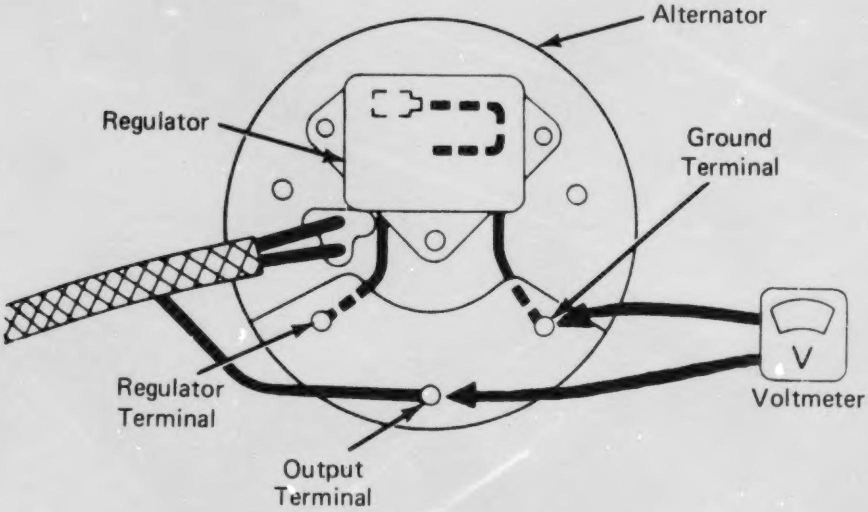
JOB SHEET #1

G. Test regulator

1. Connect the voltmeter (Figure 6)

   (NOTE: Use an accurate voltmeter, one that will measure to within plus or minus 0.1 volts.)

   FIGURE 6


Alternator
Regulator
Ground Terminal
V
Voltmeter
Regulator Terminal
Output Terminal

REGULATOR TEST CONNECTIONS

2. Run the engine to obtain a 10-amp charging rate for about 15 minutes to stabilize the regulator temperature

3. Measure the regulator temperature about one inch from the regulator and check the voltmeter reading

4. Compare the reading with manufacturer's specifications

   (NOTE: If the voltage is not within limits, the regulator is faulty.)

ALTERNATOR CHARGING CIRCUITS
UNIT VIII

JOB SHEET #2--REMOVE AND REPLACE AN ALTERNATOR

I. Tools and materials

   A. Vehicle

   B. Basic hand tool set

   C. Belt tension gauge

   D. Battery cable clamp removal tool

   E. Shop towels

   F. Safety glasses

   G. Appropriate service manual

II. Procedure

(CAUTION: Remove all jewelry prior to working on electrical system and follow all shop safety procedures.)

   A. Remove battery ground cable

   B. Remove wire leads from alternator

   (NOTE: The battery lead on the alternator will be dangerous to remove unless the battery ground cable has been removed from the battery. Alternator leads should be tagged for replacement.)

   C. Remove the alternator belt adjusting bolt

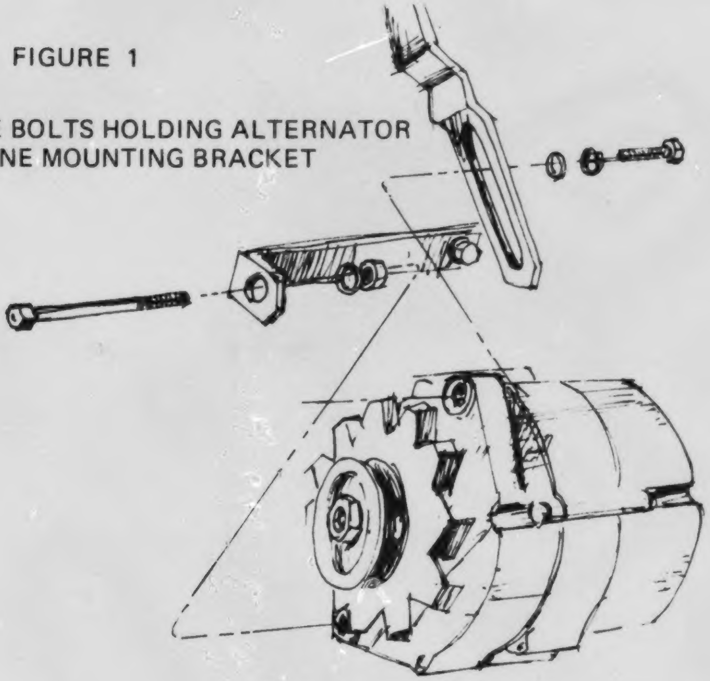
   D. Move the alternator toward the engine

   E. Remove the alternator belt from the alternator pulley

JOB SHEET #2

F. Remove the bolts holding the alternator to the engine mounting bracket (Figure 1)

FIGURE 1



REMOVE BOLTS HOLDING ALTERNATOR
TO ENGINE MOUNTING BRACKET

G. Lift the alternator out of the bracket

H. Service alternator as required

I. Position the alternator in the engine mounting bracket to replace

J. Start alternator retaining bolts and tighten securely

K. Position alternator belt on pulley and move alternator away from engine to tighten belt

L. Pry the alternator away from the engine to adjust the alternator belt tension

(NOTE: Use caution when adjusting the alternator belt to avoid damaging the alternator. Refer to manufacturer's recommendations for tightening procedures.)

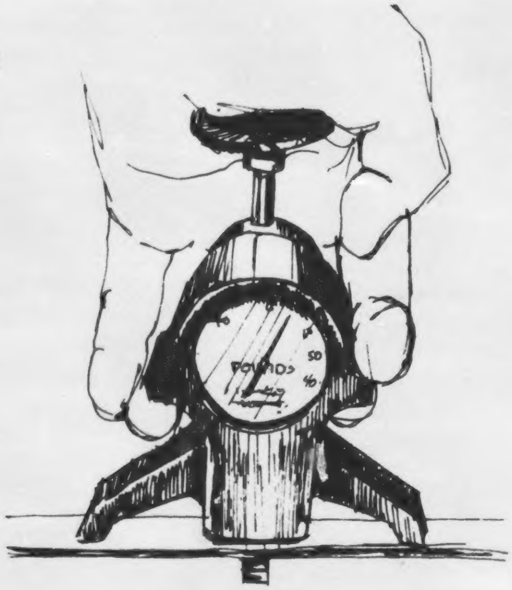
M. Install the alternator adjusting bolt

JOB SHEET #2

N. Check alternator belt tension with a belt tension gauge and adjust to manufacturer's specifications (Figure 2)

(NOTE: The alternator belt must be adjusted properly.)

FIGURE 2



CHECK BELT FOR TIGHTNESS

O. Install wire leads that were removed from the alternator and tighten securely

P. Install battery ground cable

(NOTE: Never attempt to polarize an alternator.)

ALTERNATOR CHARGING CIRCUITS
UNIT VIII

JOB SHEET #3--DISASSEMBLE, TEST, AND REASSEMBLE AN ALTERNATOR

I. Tools and materials

- A. Alternator
- B. Basic hand tool set
- C. Alternator pulley removal tools
- D. Alternator diode removal equipment
- E. Alternator testing equipment
- F. Torque wrench
- G. Shop towels
- H. Safety glasses
- I. Appropriate service manual

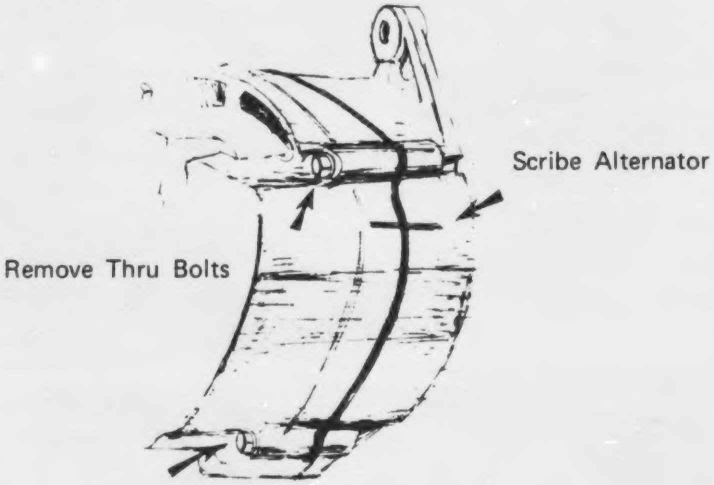
II. Procedure

(CAUTION: Remove all jewelry prior to working on electrical system and follow all shop safety procedures.)

A. Disassemble alternator

1. Scribe the alternator before disassembly (Figure 1)

FIGURE 1



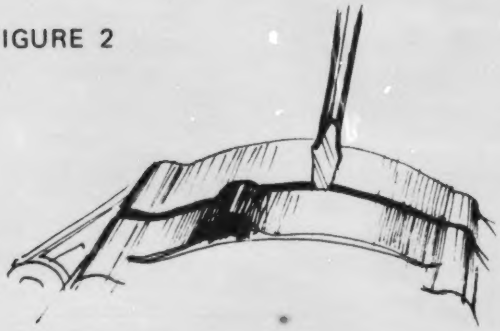
2. Remove thru bolts holding the end frames together

JOB SHEET #3

3. Pry at bolt locations to separate the drive end frame from the slip ring end frame (Figure 2)

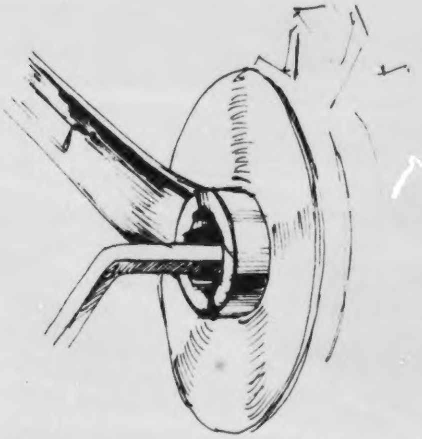
   (NOTE: Be sure stator stays with slip ring end of frame.)

FIGURE 2



4. Remove the slip ring end frame and stator (as an assembly) from drive end frame and rotor assembly
5. Remove the three stator lead attaching nuts
6. Separate stator from slip ring end frame
7. Remove screws, brushes, and brushholder assembly
8. Remove heat sink from end frame
9. Remove pulley retaining nut (Figure 3)

FIGURE 3



REMOVE PULLEY RETAINING NUT

JOB SHEET #3

10. Remove pulley and fan using pullers as required
11. Remove rotor and spacers from end frame assembly
12. Remove drive frame bearing retainer and bearing from drive end frame

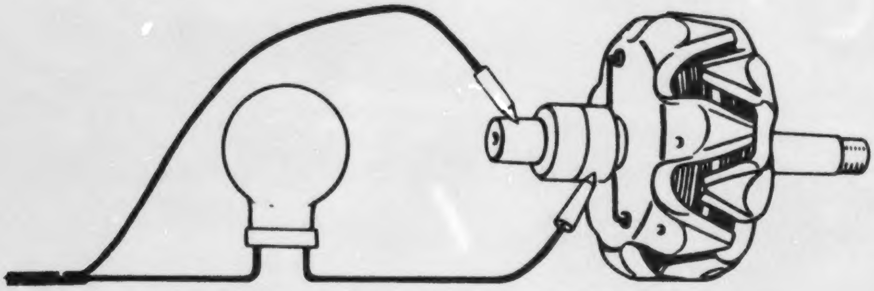
B. Service and test alternator

1. Wash all metal parts except stator, diode, and rotor assemblies
2. Clean bearings and inspect for pitting or roughness
3. Replace bearings as required
4. Inspect rotor slip rings

   (NOTE: The slip rings should be clean and free of scratches.)
5. Service as required
6. Inspect brushes for wear
7. Replace brushes as required
8. Test the rotor for grounds (Figure 4)
   a. Connect one lead of a test lamp from either slip ring to the rotor shaft
   b. Observe test light

   (NOTE: If test lamp lights, the rotor is grounded.)

FIGURE 4



TEST ROTOR FOR GROUNDS

JOB SHEET #3

9. Test the rotor for open circuit (Figure 5)

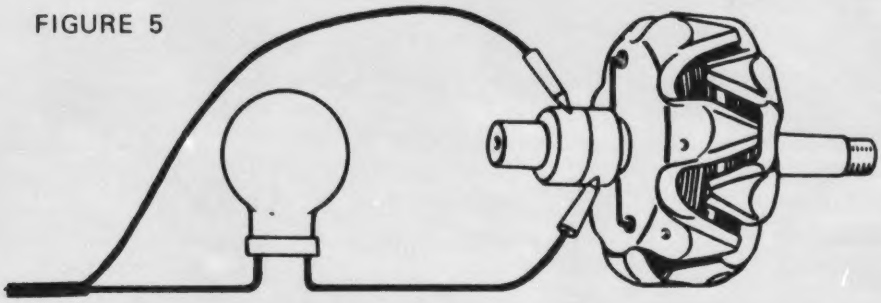
   a. Connect one lead of a test lamp to one slip ring and the other lead to the remaining slip ring

      (NOTE: Test on side of rims to keep from damaging surfaces.)

   b. Observe the test lamp

      (NOTE: If the test lamp does not light, the circuit is open.)

FIGURE 5



TEST ROTOR FOR OPENS

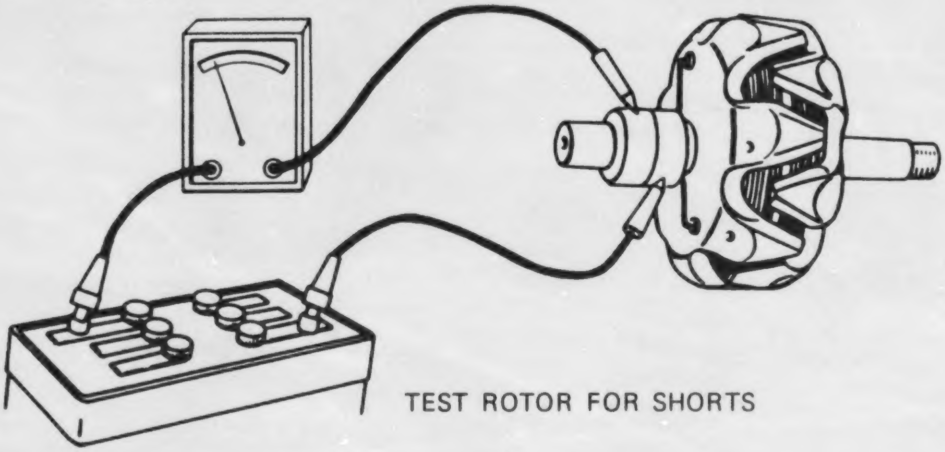
10. Test the rotor for short circuit (Figure 6)

    a. Connect a twelve-volt battery and ammeter in series with the two slip rings

    b. Read the ammeter

       (NOTE: An ammeter reading above specified field amperage draw indicates a short circuit. Refer to manufacturer's specifications.)

FIGURE 6



TEST ROTOR FOR SHORTS

JOB SHEET #3

11. Test the stator for grounds (Figure 7)

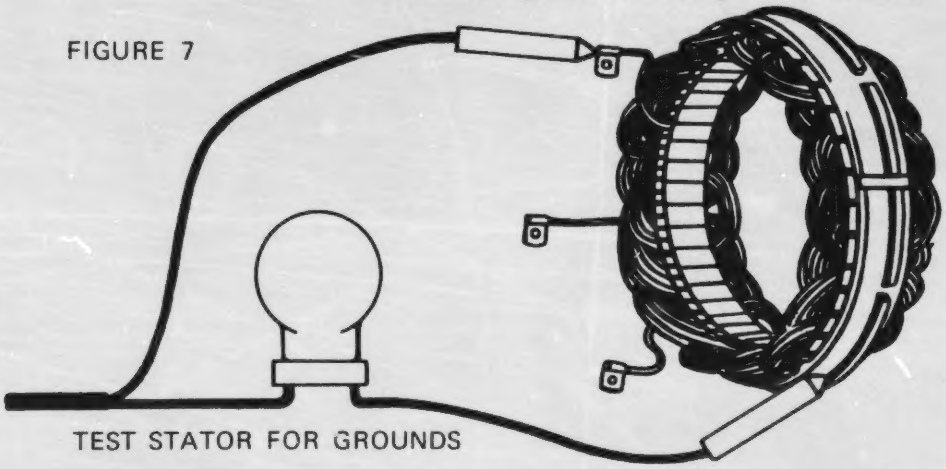
    (NOTE: Stators can be checked for ground only through output tests.)

    a. Connect one lead of a test lamp to the stator frame

    b. Connect the other lead to any stator lead

    (NOTE: If the lamp lights, the windings are grounded.)

FIGURE 7



TEST STATOR FOR GROUNDS

12. Test the stator for open circuit (Figure 8)

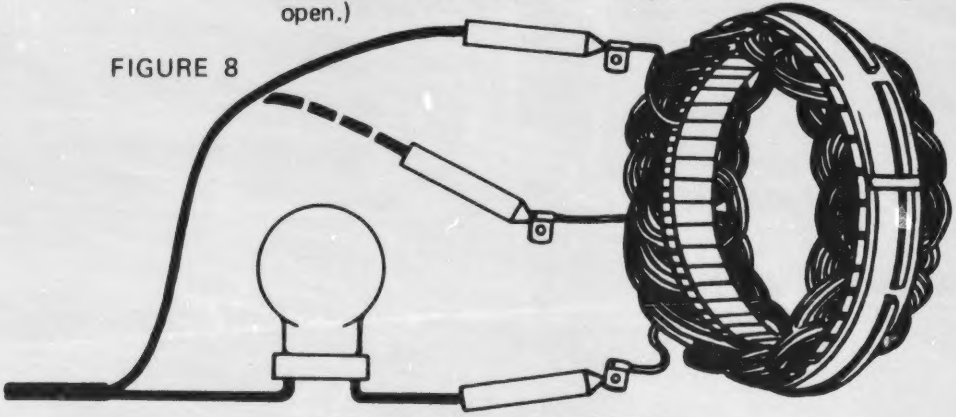
    (NOTE: This test will not work on a delta wound stator.)

    a. Connect a test lamp between each pair of stator leads

    b. Observe the test lamp

    (NOTE: If test lamp fails to light, the stator windings are open.)

FIGURE 8



TEST STATOR FOR OPENS

JOB SHEET #3

13. Test heat sink diodes

    (NOTE: If a test lamp is used instead of an ohmmeter, voltage should be 12 volts or less.)

    a. Zero ohmmeter if used

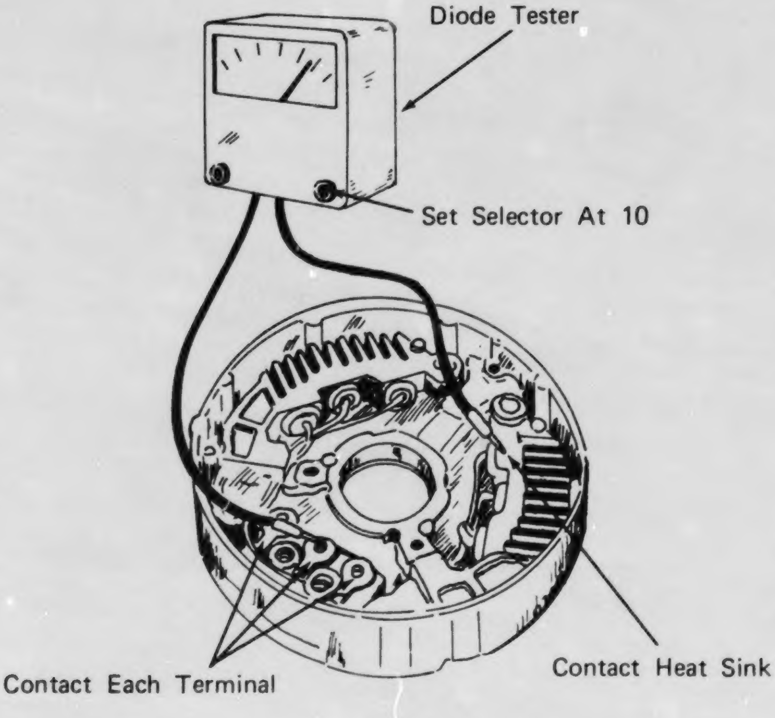
    b. Test positive diodes (Figure 9)

        1) Touch one lead or probe to positive heat sink

        2) Touch one lead to stator lead terminals one at a time

        3) Reverse leads to check flow in opposite direction

FIGURE 9


Diode Tester
Set Selector At 10
Contact Each Terminal
Contact Heat Sink

DIODE TEST

JOB SHEET #3

14. Test the end frame diodes

    a. Connect one lead of a twelve-volt test lamp to end frame

    b. Connect the other lamp lead to the diode lead

    (NOTE: If lamp lights in both directions or fails to light at all, the diode is defective.)

    c. Replace any parts found defective

    d. Replace any diodes found defective

    NOTE: Use proper diode removal and replacement tools.)

15. Replace slip ring end frame bearing assembly, if grease supply is exhausted

    (NOTE: Make no attempt to relubricate and reuse bearings.)

16. Repack drive end bearings with proper lubricant

C. Reassemble alternator

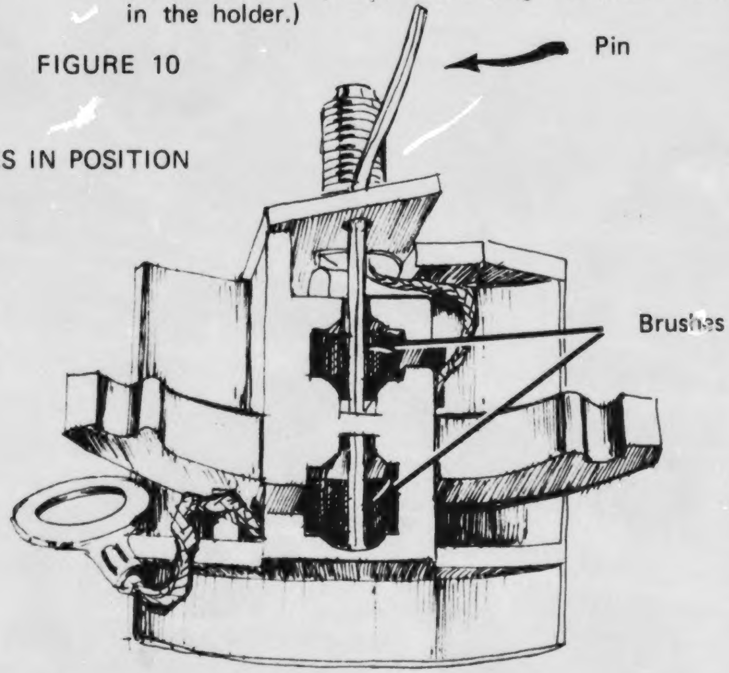
1. Assemble heat sink to end frame

2. Install brush holder and brushes into slip ring end frame (Figure 10)

    (NOTE: Insert a pin or wire through the hole to hold the brushes in the holder.)

FIGURE 10

BRUSHES IN POSITION



JOB SHEET #3

3. Install stator assembly in slip ring end frame and locate diode connectors over the relay, diode, and stator leads

4. Install and tighten terminal nuts securely

5. Install bearing in drive end frame

6. Install rotor in drive end frame

7. Install fan, spacer, pulley, and retaining nut

8. Tighten nut to manufacturer's specifications

9. Assemble slip ring, end frame, and stator assembly to drive end frame and rotor assembly

   (NOTE: Align end frames by referring to scribe marks put on during disassembly.)

10. Install thru bolts in the end frame assembly

11. Tighten bolts securely

12. Remove wire holding brushes in place

13. Check alternator operation

    (NOTE: The brushless alternator checks are made in the same manner, except for the regulator which requires a special tester.)

ALTERNATOR CHARGING CIRCUITS
UNIT VIII

JOB SHEET #4--TEST AND REPAIR A TRANSISTORIZED REGULATOR

I. Tools and materials

- A. Vehicle
- B. Basic hand tool set
- C. Voltmeter
- D. Carbon pile resistor
- E. Ammeter
- F. Jumper wire
- G. Safety glasses
- H. Appropriate service manual

II. Procedure

(CAUTION: Remove all jewelry prior to working on electrical system and follow all shop safety procedures.)

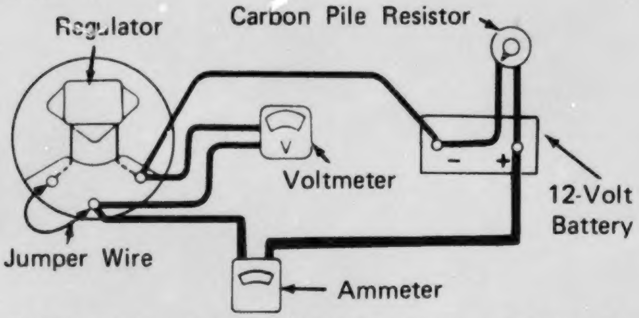
(NOTE: For a particular test procedure always follow the equipment technical manual.)

A. Test regulator voltage

(NOTE: This test can be performed either on or off the machine. Use an alternator that is known to be in good repair.)

1. Set up the test circuit (Figure 1)

FIGURE 1



VOLTAGE TEST FOR TRANSISTORIZED REGULATOR

2. Connect a voltmeter to the alternator ground and output terminals (Figure 1)

(NOTE: Be sure to use a voltmeter with an accuracy within 0.1 volts.)

JOB SHEET #4

3. Start the engine, momentarily connect jumper wire to excite the field, and apply a load of about 10 amperes (use lights, motors, carbon pile resistors, etc.)

4. Operate the circuit for about 15 minutes to stabilize the temperature of the regulators

5. Measure and record the temperature about one inch from the regulator case

6. Compare the voltmeter reading with the voltage specifications listed in the machine technical manual

7. Adjust the reading for the temperature recorded above

B. Adjust and repair transistorized regulator

1. Use adjusting screw to change the operating voltage for different conditions

   (NOTE: This may not be used on some transistorized regulators.)

2. Since most transistorized regulators are sealed units, repair by replacing if they are found faulty

   (NOTE: This type of regulator is usually more reliable than other kinds.)

ALTERNATOR CHARGING CIRCUITS
UNIT VIII

JOB SHEET #5--TEST AN ALTERNATOR WITH AN I.C. REGULATOR

I. Tools and materials

   A. Vehicle

   B. Voltmeter

   C. Ammeter 0-75 amp rating or higher

   D. Carbon pile

   E. Screwdriver

   F. Clean shop towels

   G. Basic shop tools

   H. Appropriate shop manual

II. Procedure

(CAUTION: Remove all jewelry prior to working on electrical system and follow all shop safety procedures.)

(NOTE: Before testing, all accessories must be turned off and if blower motor runs at all times the lead from it should be disconnected.)

   A. Check and adjust belt tension

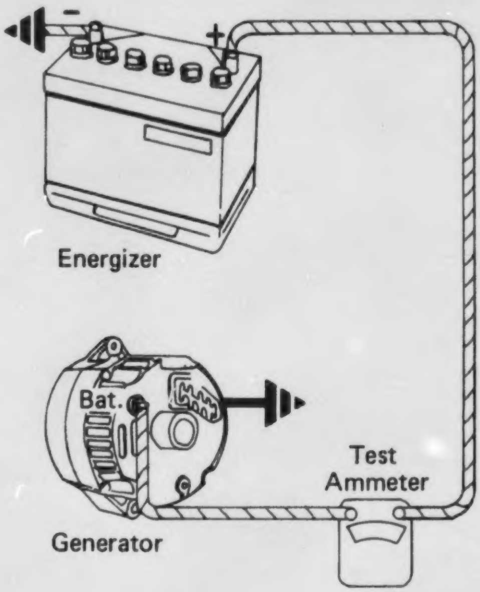
   (CAUTION: Disconnect battery ground cable to protect test instruments while hooking them up.)

   B. Disconnect the battery terminal lead from the alternator

JOB SHEET #5

C. Connect the ammeter to the battery terminal and wire that was on the alternator (Figure 1)

FIGURE 1

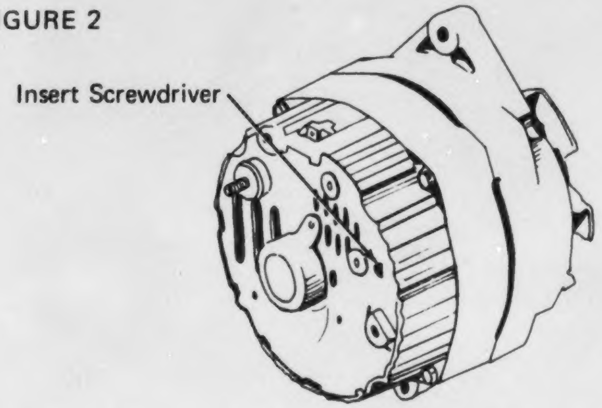

−
+
Energizer
Bat.
Test
Ammeter
Generator

D. Start the engine and run up to test rpm

(NOTE: Refer to manufacturer's recommended rpm.)

E. Use a small screwdriver and insert it in the D shaped hole in back of alternator and ground the small tab to the alternator housing (Figure 2)

FIGURE 2


Insert Screwdriver

F. Note the ammeter reading; it should be within 10% of specified output

ALTERNATOR CHARGING CIRCUITS
UNIT VIII

NAME_______________________________

TEST

1. Match terms on the right with their correct definitions.

_____a. Wire coil wrapped around an iron core and mounted on a rotating shaft

_____b. Laminated soft iron ring wth three groups of coils

_____c. Device that allows current to flow in one direction and blocks current in opposite direction

_____d. Metal conductors in the form of a ring, fastened to each end of coil and mounted on rotor shaft

_____e. Wire touching another wire and providing a shorter path for current to flow

_____f. Circuit in which a wire is broken or disconnected

_____g. Circuit in which a wire touches ground causing the current to flow to ground instead of through the circuit

_____h. Fully electronic unit composed of resistors, diodes, zener diodes, transistors, and thermistor

_____i. Dissipates heat from diodes

_____j. An alternator that has neither slip rings nor brushes

_____k. Acts as a voltage divider or voltage adjustment

1. Open circuit
2. Potentiometer
3. Transistorized regulator
4. Brushless alternator
5. Stator
6. Heat sink
7. Grounded circuit
8. Short circuit
9. Slip rings
10. Rotor
11. Diode

2. State the purpose of the alternator charging circuit.

____

____

3. Match the alternator charging circuit components on the right with their correct functions.

_____a. Starts the circuit by supplying spark to start engine, helps out during peak operation when electrical load is too much for alternator, and stabilizes system voltage

_____b. Measures the rate of current flow

_____c. Supplies electrical power to accessory circuits and recharges battery

_____d. Indicates produced voltage

_____e. Limits the alternator voltage to a safe, preset value

_____f. Indicates problems in system; used in place of a meter

1. Indicator lights
2. Ammeter
3. Alternator
4. Regulator
5. Battery
6. Voltmeter

4. Identify the major parts of an alternator.

a. ______________________________

b. ______________________________

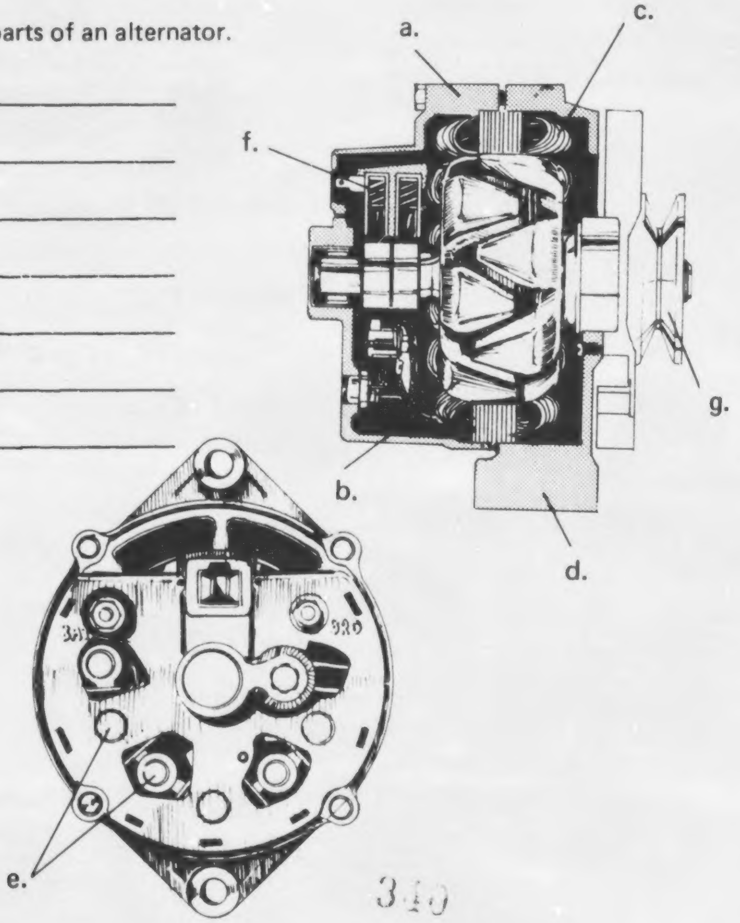
c. ______________________________

d. ______________________________

e. ______________________________

f. ______________________________

g. ______________________________



5. Distinguish between an alternator and a generator by placing an "X" next to the descriptions of an alternator.

   _____a. Rotates the field inside the stationary windings

   _____b. Rectifies AC current to DC through the use of a segmented commutator and brushes

   _____c. Rotates the windings inside the field

   _____d. Rectifies the AC current to DC with a series of diodes

6. List two advantages of an alternator as opposed to a generator.

   a. ____

   b. ____

7. Explain why an alternator produces more current at low speed than a generator.

   ____

   ____

8. Discuss the construction of stator windings.

   ____

   ____

9. Discuss how an alternator is controlled by a regulator.

   ____

   ____

10. Select true statements concerning a brushless alternator by placing an "X" in the appropriate blanks.

    _____a. Is a low mileage unit

    _____b. Is used on diesel engines only

    _____c. Regulator compartment is non-vented

    _____d. Uses large bushings at both ends

    _____e. Has extra large grease reservoirs

    _____f. Has extra small lip seal to keep grease in, and dirt out

    _____g. Regulator compartment is air tight

    _____h. Designed to operate between engine overhauls without attention

11. Select true statements concerning operation of a brushless alternator by placing an "X" in the appropriate blanks.

______a. To generate voltage in the stator windings it is only necessary for the rotor to cause alternating north and south magnetic lines to cut across the stator windings

______b. The field coil is mounted to the end frame

______c. The rotor is mounted on bearings and fits between the stator and field coil

______d. The field coil produces a north pole at the right hand side of the coil

______e. Magnetic lines cross the air gap between the field coil and rotor to make all the right hand rotor poles all north poles

______f. The non-magnetic lines of force cannot go through the non-magnetic ring directly; instead they pass through the air gap into the left hand, south magnetic poles of the rotor; the magnetic lines then cross the air gap between the rotor and field coil and then into the field coil to complete the magnetic path

______g. The non-magnetic ring has diverted the magnetic field into the stator windings, and as the rotor turns, AC voltage is generated in the stator windings

12. Match the component parts of a transistorized regulator on the right with their correct functions.

______a. Devices made of wire or carbon which produce a resistance to current flow

______b. Diode connected in a reverse bias, which will conduct a reverse current beyond a predetermined voltage

______c. Semiconductors which control the flow of current by either allowing it to flow or stopping it

______d. Temperature-compensated resistor whose degree of resistance varies with the temperature

1. Transistor
2. Thermistor
3. Resistors
4. Zener diode

13. Select true statements concerning the operation of a transistorized regulator by placing an "X" in the appropriate blanks.

______a. Allows battery current to excite the alternator field coils

______b. Controls charging voltage at safe values during operation

14. List five safety rules for working with an alternator charging circuit.

    a. ____

    b. ____

    c. ____

    d. ____

    e. ____

15. Demonstrate the ability to:

    a. Test the alternator charging circuit and regulator.

    b. Remove and replace an alternator.

    c. Disassemble, test, and reassemble an alternator.

    d. Test and repair a transistorized regulator.

    e. Test an alternator with an I.C. regulator

    (NOTE: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

ALTERNATOR CHARGING CIRCUITS
UNIT VIII

ANSWERS TO TEST

1. a. 10
   b. 5
   c. 11
   d. 9
   e. 8
   f. 1
   g. 7
   h. 3
   i. 6
   j. 4
   k. 2

2. The alternator charging circuit recharges the battery and maintains a supply of electrical current to meet the operating needs of the equipment

3. a. 5
   b. 2
   c. 3
   d. 6
   e. 4
   f. 1

4. a. Drive end frame
   b. Rotor assembly
   c. Stator assembly
   d. Slip ring end frame
   e. Diodes
   f. Brush assembly
   g. Pulley

5. a, d

6. a. Produces higher output at lower engine speeds
   b. Simplicity in construction requires less maintenance and space

7. Explanation should include--Alternator has more pole pieces than the generator so that many more magnetic lines of force are cut during one revolution of the rotor

8. Discussion should include--Windings have three phases or groups of windings, with each winding connected to a positive and negative diode

9. Discussion should include--Regulator places a resistence in the field circuit which reduces current flow to the alternator rotor

10. e, g, h

11. a, b, c, d, e, f, g

12. a. 3
    b. 4
    c. 1
    d. 2

13. a, b

14. Any five of the following:

    a. Never attempt to polarize the circuit

    b. Be sure the battery is in good operating condition before making any tests or adjustments

    c. Never operate the alternator in an open circuit, except when instructed in the technical manual

    d. Never short or ground the alternator terminals

    e. Do not disconnect the voltage regulator while the alternator is running

    f. Disconnect the negative battery cable first when removing the alternator or battery

    g. Do not use acid-core solder on the alternator terminals; use only a rosin-core solder

    h. Never immerse the circuit components in cleaning solution

15. Performance skills evaluated to the satisfaction of the instructor

EMERGENCY SHUT-DOWN CIRCUITS
UNIT IX

UNIT OBJECTIVE

After completion of this unit, the student should be able to list the characteristics of a temperature controlled system and arrange in order the operation of the oil pressure and water temperature shut-off switches. The student should also be able to troubleshoot the contactor switch for water temperature and test a shut-off and alarm system. This knowledge will be evidenced by correctly performing the procedures outlined in the job sheets and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to emergency shut-down circuits with their correct definitions.
2. List the characteristics of a temperature controlled system.
3. Select true statements concerning shut-off solenoids.
4. Select true statements concerning the overspeed contactor switch.
5. Complete a list of functions of a pressure switch.
6. Arrange in order the operation of the oil pressure and water temperature shut-off switches.
7. Select true statements concerning the oil pressure contactor switch.
8. Complete a list of statements concerning the operation of an alarm system.
9. Demonstrate the ability to:
   a. Troubleshoot the contactor switch for water temperature.
   b. Test a shut-off and alarm system.

EMERGENCY SHUT-DOWN CIRCUITS
UNIT IX

SUGGESTED ACTIVITIES

I. Provide student with objective sheet.

II. Provide student with information and job sheets.

III. Make transparencies.

IV. Discuss unit and specific objectives.

V. Discuss information sheet.

VI. Demonstrate and discuss the procedures outlined in the job sheets.

VII. Demonstrate to the class how to install an emergency shut-down circuit.

VIII. Discuss safety procedures pertaining to emergency shut-down circuits.

IX. Take a field trip to at least 3 different truck shops to see different types of shut-down circuits.

(NOTE: Shut-down circuits can also be found anywhere that emergency generators are located, such as, in hospitals, in shopping centers, on combines, and on irrigation systems.)

X. Give test.

INSTRUCTIONAL MATERIALS

I. Included in this unit:

- A. Objective sheet
- B. Information sheet
- C. Transparency masters
    1. TM 1--Typical Shut-Down Switches
    2. TM 2--Typical Shut-Down Switches (Continued)
    3. TM 3--Typical Shut-Down Device and Wiring Diagram
    4. TM 4--Oil Flow Schematic
    5. TM 5--Wiring Diagram for Alarm System

D. Job sheets

1. Job Sheet #1--Troubleshoot the Contactor Switch for Water Temperature

2. Job Sheet #2--Test a Shut-Off and Alarm System

E. Test

F. Answers to test

II. References:

A. *3406 Industrial and Marine Engines.* Peoria, IL: Caterpillar Tractor Co., 1979.

B. *Fundamentals of Service: Electrical Systems.* Fourth Edition. Moline, IL: Deere and Company, 1979.

C. Dagel, John F. *Diesel Engine Repair.* New York: John Wiley and Sons, Inc., 1982.

D. *Detroit Diesel Allison, In-Line 71 Service Manual.* Detroit, MI: General Motors Corp., 1981.

EMERGENCY SHUT-DOWN CIRCUITS
UNIT IX

INFORMATION SHEET

I. Terms and definitions

- A. Switch--Electrical or mechanical device that opens or closes a circuit
- B. Magnetic switch--Same as a solenoid but does not have an activating device
- C. Solenoid--An electric coil with a moveable iron core; when current flows through the coil, it forms a magnet and the iron core moves to activate a device
- D. Temperature sending unit--Monitors engine coolant temperature
- E. Heat sink--Usually a piece of metal that is used to absorb or dissipate heat away from a heat sensitive device
- F. Normally open switch--A switch that is activated either manually or electrically and returns to the open position when released
- G. Normally closed switch--A switch that is activated by an electrical signal to shut down a device or an engine
- H. Flow control switch--Senses coolant flow through system and warns operator of immediate shut-down
- I. Overspeed governor--Protects engine from excessive rpm

  (NOTE: This is also known as an overspeed trip.)
- J. Murphy switch--An automatic shut-down switch for coolant, oil, and fuel systems

II. Temperature controlled system

- A. Uses a coolant temperature contactor switch
- B. Works in conjunction with a shut-off solenoid
- C. Can be used with oil pressure switch

III. Shut-off solenoids (also called rack shut-off solenoid) (Transparencies 1, 2, and 3)

- A. Energized by any of the following:
  1. Water temperature contactor switch
  2. Oil pressure contactor switch

INFORMATION SHEET

3. Overspeed contactor switch

4. Manual control switch

B. Work by overriding the governor and moving the fuel rack to the shut-off position

C. Shut off fuel supply

IV. Overspeed contactor switch

A. Mounted to the tachometer drive

B. When the engine overspeeds, the contact points close and send a signal to the shut-off solenoid

C. If the overspeed contactor switch is activated, it will have to be reset

V. Pressure switch

A. Used in automatic start-stop system

B. De-energizes the rack solenoid after engine shut-down

VI. Oil pressure and water temperature shut-off (Transparency 4)

A. Pressurized oil enters line #1 from the auxiliary oil manifold #2

B. The oil then flows behind the control piston in the oil pressure and overspeed shut-off control #3

C. Pressurized oil then flows through line #5 to the water temperature shut-off valve #6

D. When the engine reaches too high a temperature, the valve opens and dumps the oil back into the oil pan

E. The oil pressure switch senses the drop in oil pressure and signals the shut-off solenoid, which shuts off the engine

VII. Oil pressure contactor switch

A. Is an electric switch

B. Signals the shut-off solenoid

C. On automatic start-stop systems, a double set of contacts opens to disconnect the starter solenoid

INFORMATION SHEET

VIII. Alarm systems (Transparency 5)

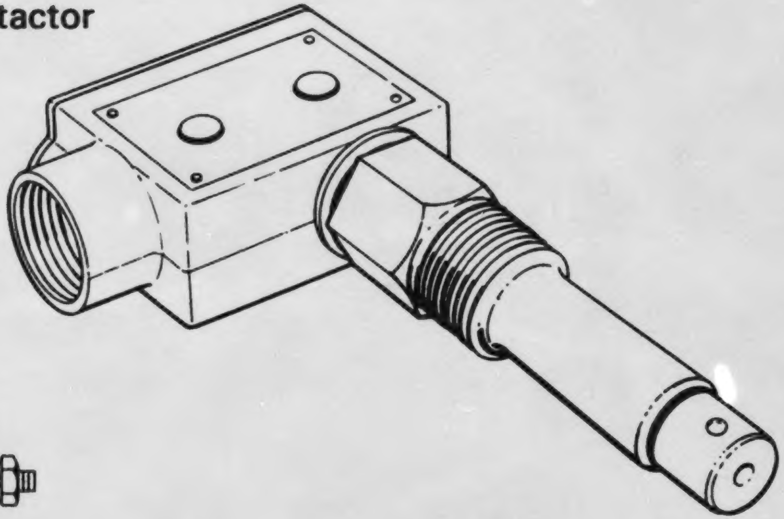
A. Uses a light in the dash to warn driver of system failure

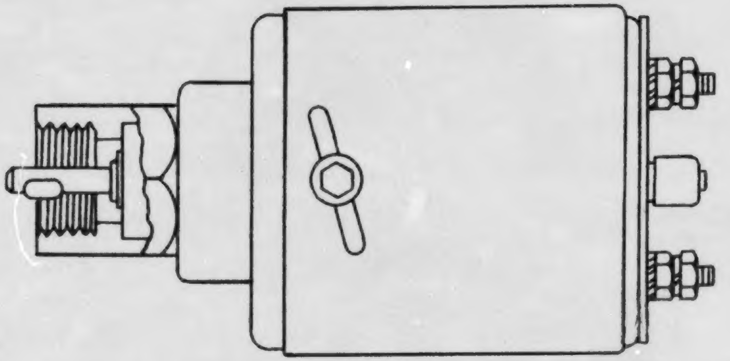
B. Uses a horn to warn driver of system failure

C. Has to be reset after engine has been stopped

Typical Shut-Down Switches

Temperature Contactor
Switch

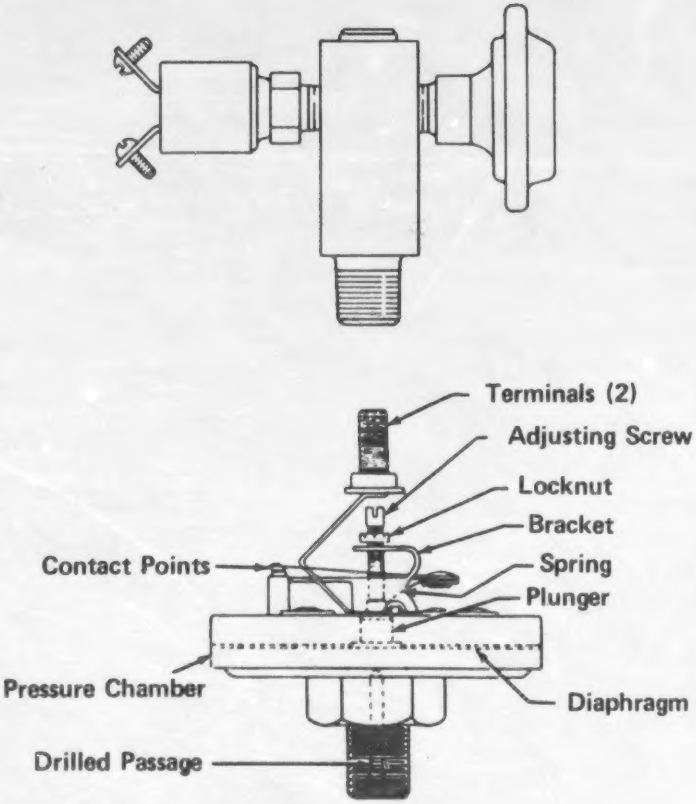




Overspeed Contactor
Switch

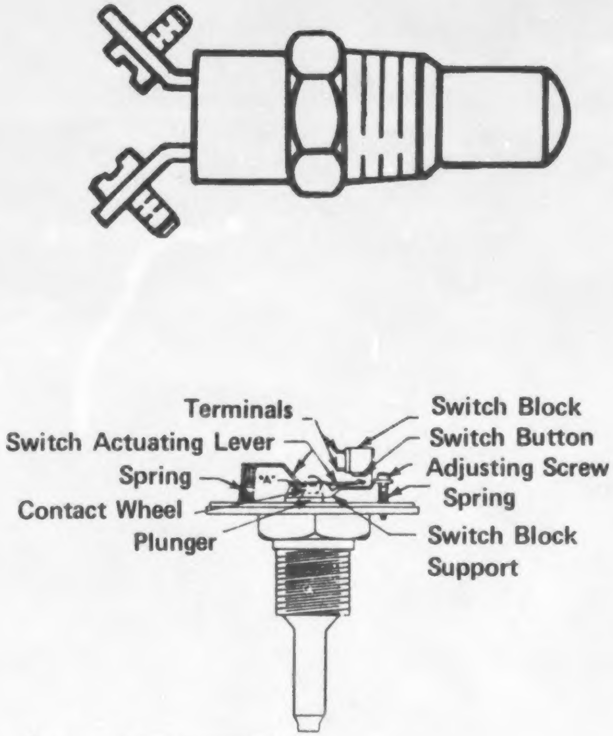
Typical Shut-Down Switches

(Continued)


Terminals (2)
Adjusting Screw
Locknut
Bracket
Spring
Plunger
Contact Points
Pressure Chamber
Diaphragm
Drilled Passage

© General Motors Corporation

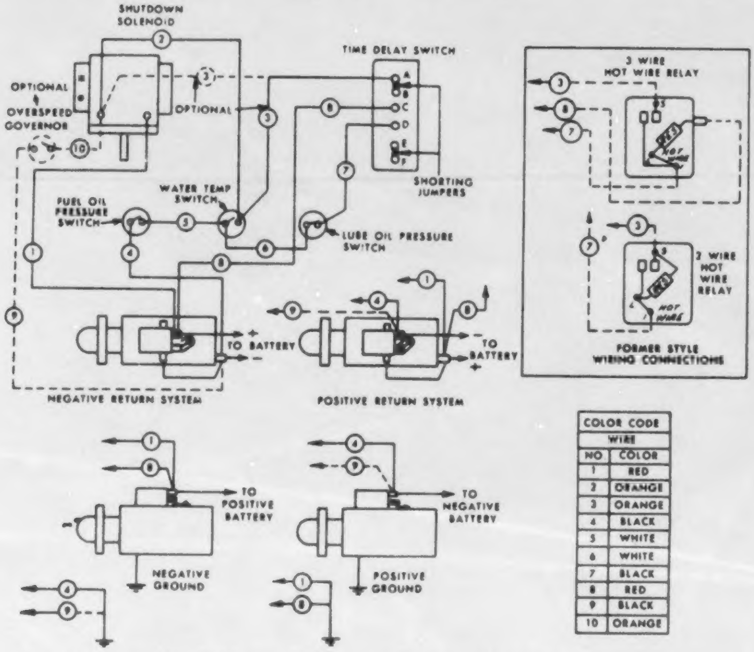
Oil Pressure Switch


Terminals
Switch Actuating Lever
Spring
Contact Wheel
Plunger
Switch Block
Switch Button
Adjusting Screw
Spring
Switch Block
Support
"A"

© General Motors Corporation

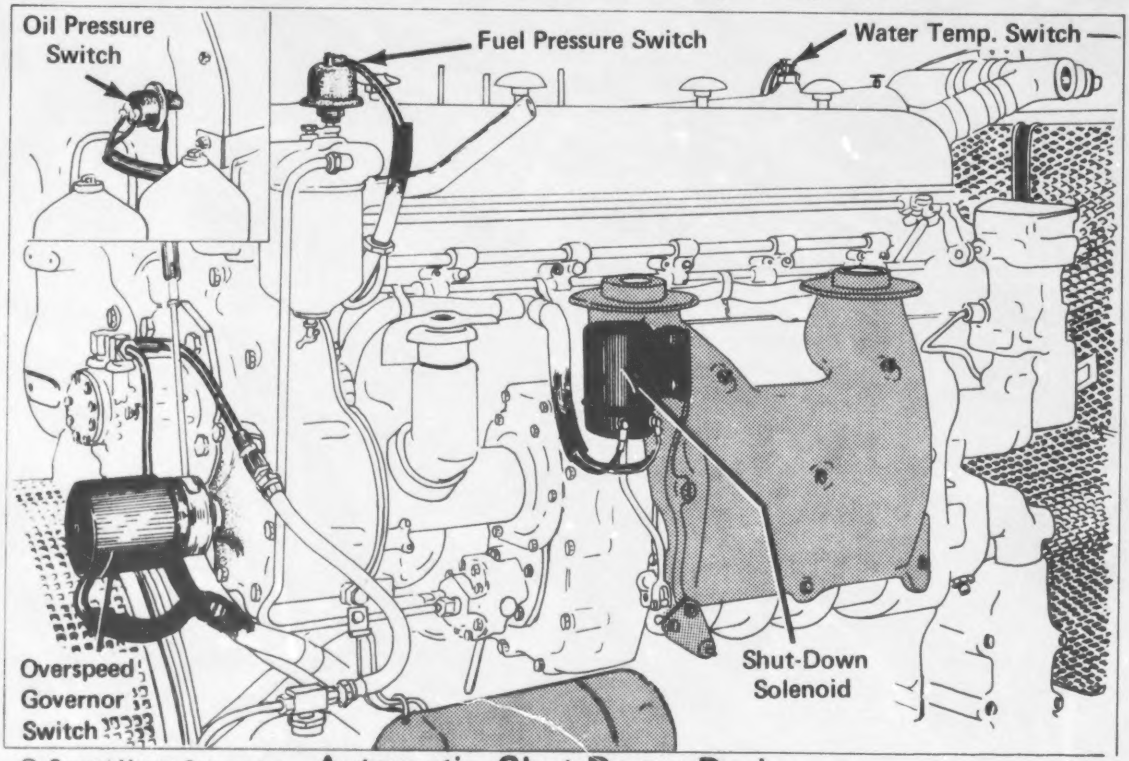
Low Water Temperature Switch

Typical Shut-Down Device and Wiring Diagram


SHUTDOWN SOLENOID
OPTIONAL & OVERSPEED GOVERNOR
OPTIONAL
TIME DELAY SWITCH
A
B
C
D
E
F
SHORTING JUMPERS
FUEL OIL PRESSURE SWITCH
WATER TEMP SWITCH
LUBE OIL PRESSURE SWITCH
TO BATTERY
TO BATTERY
NEGATIVE RETURN SYSTEM
POSITIVE RETURN SYSTEM
3 WIRE HOT WIRE RELAY
HOT WIRE
2 WIRE HOT WIRE RELAY
HOT WIRE
FORMER STYLE WIRING CONNECTIONS
TO POSITIVE BATTERY
TO NEGATIVE BATTERY
NEGATIVE GROUND
POSITIVE GROUND
1
2
3
4
5
6
7
8
9
10

COLOR CODE	
WIRE	
NO	COLOR
1	RED
2	ORANGE
3	ORANGE
4	BLACK
5	WHITE
6	WHITE
7	BLACK
8	RED
9	BLACK
10	ORANGE

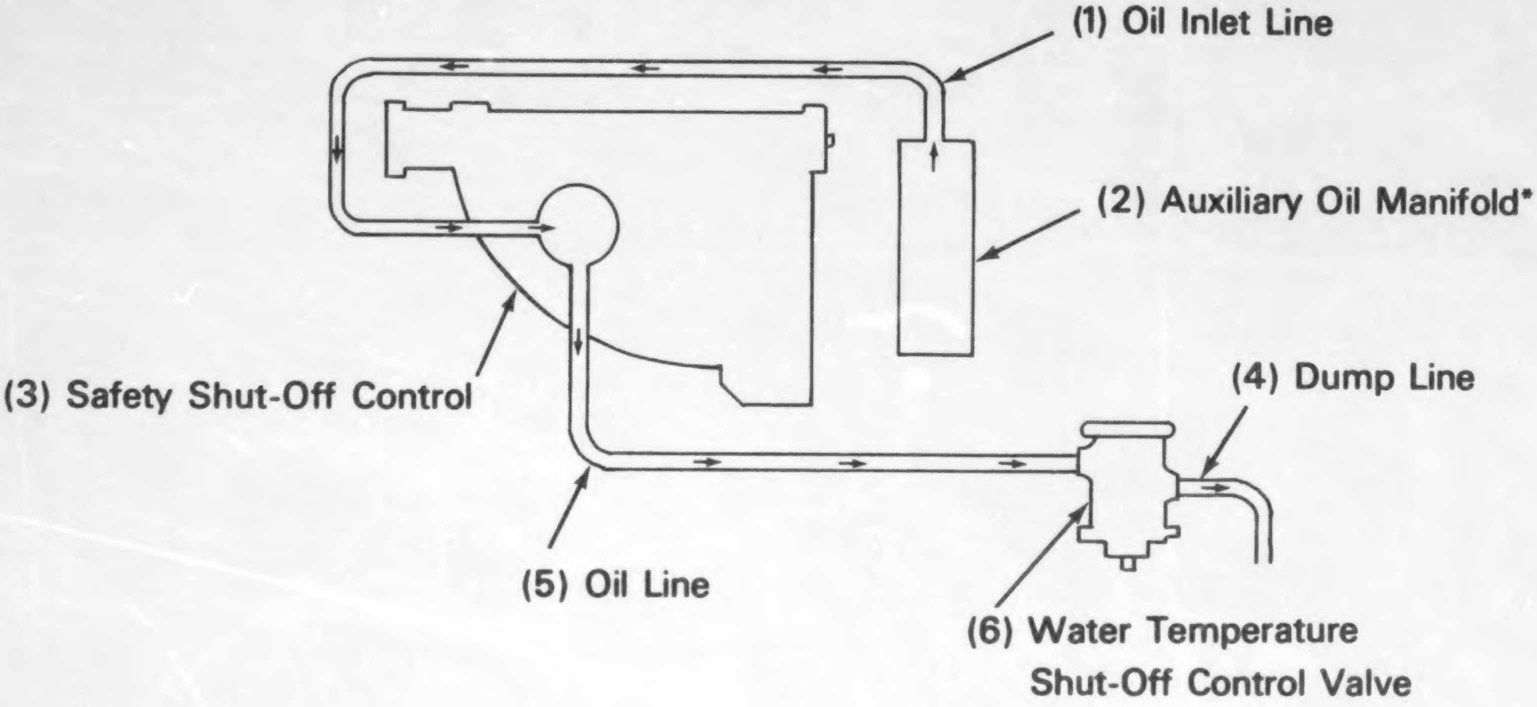
Automatic Shut-Down Wiring Diagram


Oil Pressure Switch
Fuel Pressure Switch
Water Temp. Switch
Overspeed Governor Switch
Shut-Down Solenoid

© General Motors Corporation

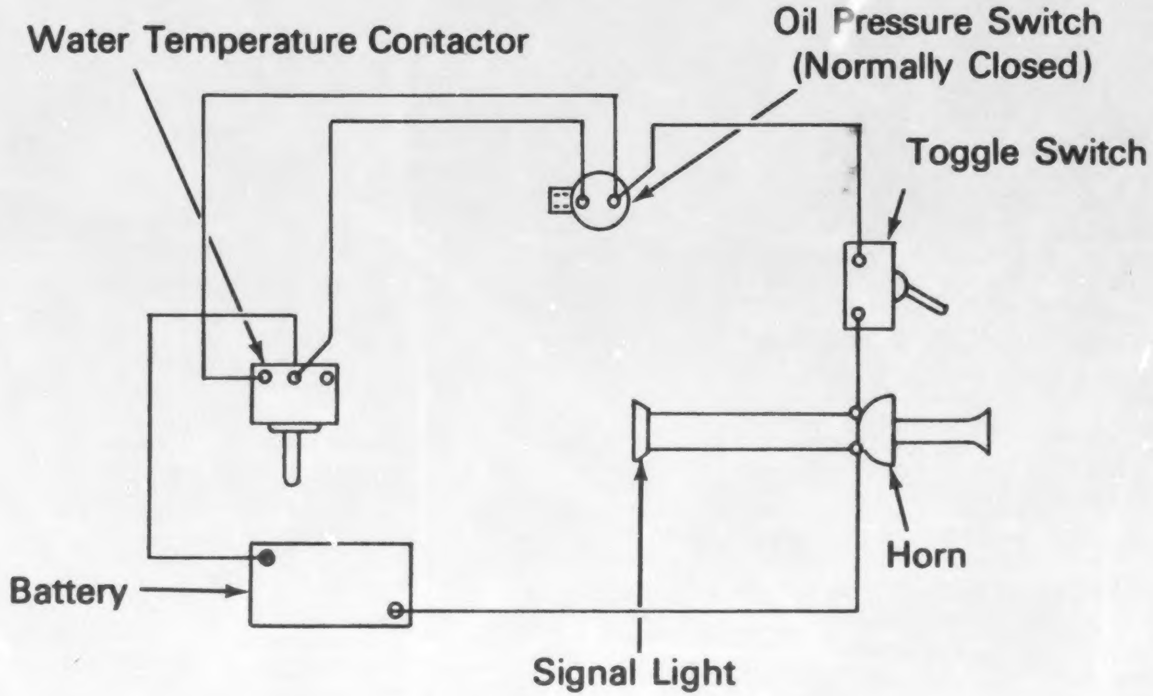
Automatic Shut-Down Device

Oil Flow Schematic


(1) Oil Inlet Line
(2) Auxiliary Oil Manifold*
(3) Safety Shut-Off Control
(4) Dump Line
(5) Oil Line
(6) Water Temperature Shut-Off Control Valve

*On later engines the oil inlet line connects to the junction block welded to the aftercooler.

Wiring Diagram for Alarm System


Water Temperature Contactor
Oil Pressure Switch
(Normally Closed)
Toggle Switch
Horn
Battery
Signal Light

High Water Temperature and Low Oil Pressure Alarm System

EMERGENCY SHUT-DOWN CIRCUITS
UNIT IX

JOB SHEET #1--TROUBLESHOOT THE CONTACTOR SWITCH FOR WATER TEMPERATURE

I. Tools and materials

A. Contactor switch

B. Metal block for heat sink

C. Thermometer 0-220°F

D. Circuit tester or equivalent (12 volt test light)

E. Basic hand tool set

F. Metal pan

G. Heating torch

H. Drill motor

I. Drill bit 23/32"

J. Pipe tap 1/2" NPT

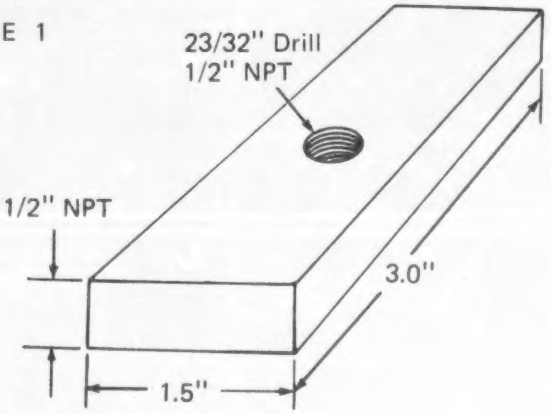
K. Appropriate service manual

II. Procedure

(CAUTION: Remove all jewelry before working on any electrical circuit and follow all shop safety procedures.)

A. Use brass, steel, or cast iron to make a heat sink with the dimensions shown (Figure 1)

FIGURE 1

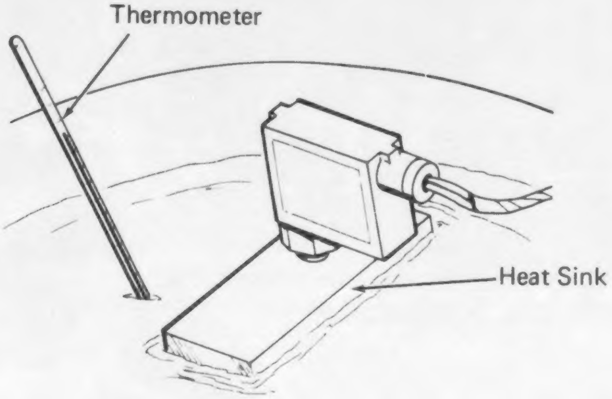


B. Put identification marks on two wires that connect the contactor to the circuit and disconnect the wires

C. Remove the contactor and install a pipe plug in its place

D. Install the contactor in the heat sink and place in water; use blocks to support heat sink (Figure 2)

FIGURE 2



E. Connect continuity light to the contactor leads

F. Place the thermometer in the water (Figure 2)

G. Use a torch and heat the water to the recommended temperature range; the contactor should activate

(NOTE: Refer to manufacturer's specifications.)

H. Replace the contactor if the continuity light does not come on within the temperature range specifications

I. Let the water cool down, and if the continuity light does not go off, replace the contactor

EMERGENCY SHUT-DOWN CIRCUITS
UNIT IX

JOB SHEET #2--TEST A SHUT-OFF AND ALARM SYSTEM

I. Tools and materials

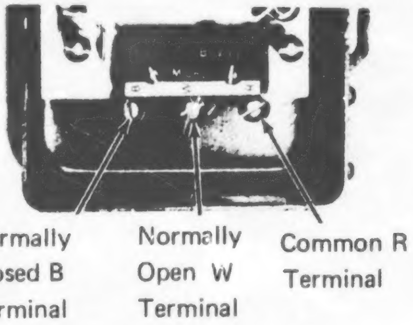
- A. Vehicle
- B. Pressure gauge 0-60 p.s.i.
- C. Pipe nipple 1/8" x 3.5"
- D. Cap
- E. Two pipe nipples 1/8" x 2"
- F. Two shut off cock fittings
- G. Three tees of various sizes
- H. Two hose assemblies
- I. Circuit tester (12 volt test light)
- J. Basic hand tool set
- K. Clean shop towels
- L. Jumper wire 12" with alligator clips
- M. Metal pan
- N. Appropriate service manual

II. Procedure

(CAUTION: Remove all jewelry before working on any electrical circuit and follow all shop safety procedures.)

A. Remove the cover from the switch and remove the wires from the normally closed switch (Figure 1)

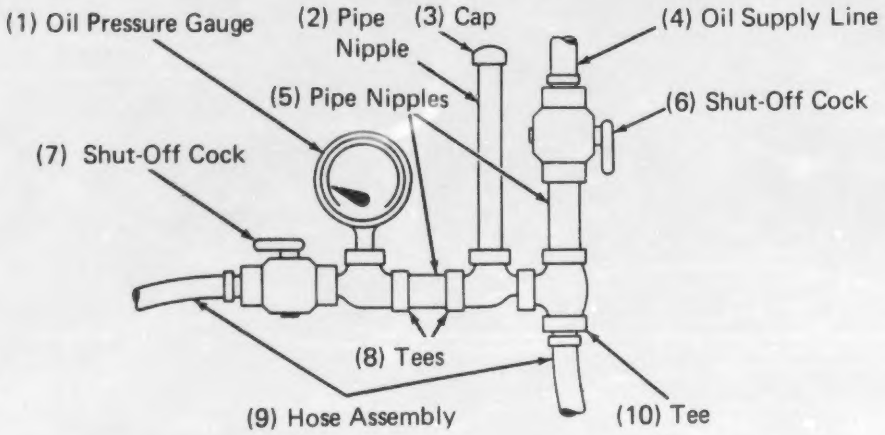
FIGURE 1



JOB SHEET #2

B. Disconnect the oil supply line from the switch and install the test equipment (Figure 2)

FIGURE 2


(1) Oil Pressure Gauge
(2) Pipe Nipple
(3) Cap
(4) Oil Supply Line
(5) Pipe Nipples
(6) Shut-Off Cock
(7) Shut-Off Cock
(8) Tees
(9) Hose Assembly
(10) Tee

C. Connect the hose from tee #10 to the switch; place the other hose from the #7 shut-off cock into the pan

D. Connect the circuit tester between the common and normally closed terminal; the light will light on the tester

E. Close the #7 fitting and open the #6 fitting

F. Look at the pressure gauge while having someone start the engine; the light on the tester must go out when the oil pressure reaches test specifications; if it does not, replace the switch

G. Close shut-off cock #6 and slowly open shut-off cock #7; the light should come on; if not, replace the switch

EMERGENCY SHUT-DOWN CIRCUITS
UNIT IX

NAME________________________________

TEST

1. Match terms on the right with their correct definitions.

_____a. Electrical or mechanical device that opens or closes a circuit

_____b. Same as a solenoid but does not have an activating device

_____c. An electric coil with a moveable iron core; when current flows through the coil it forms a magnet and the iron core moves to activate a device

_____d. Maintains engine coolant temperature

_____e. Usually a piece of metal that is used to absorb or dissipate heat away from a heat sensitive device

_____f. A switch that is activated either manually or electrically and returns to the open position when released

_____g. A switch that is activated by an electrical signal to shut down a device or an engine

_____h. Senses coolant flow through system and warns operator of immediate shut-down

_____i. Protects engine from excessive rpm

_____j. An automatic shut-down switch for coolant, oil, and fuel systems

1. Temperature sending unit
2. Normally closed switch
3. Overspeed governor
4. Switch
5. Solenoid
6. Heat sink
7. Normally open switch
8. Murphy switch
9. Magnetic switch
10. Flow control switch

2. List the characteristics of a temperature controlled system.

a. ____

b. ____

c. ____

3. Select true statements concerning shut-off solenoids by placing an "X" in the appropriate blanks.

   (NOTE: A statement is true only if all parts of the statement are true.)

   _____a. Energized by any of the following:

   1) Water temperature contactor switch
   2) Oil pressure contactor switch
   3) Overspeed contactor switch
   4) Manual control switch

   _____b. Works by overriding the governor and moving the control switch to the shut-off position

   _____c. Shut off fuel supply

4. Select true statements concerning the overspeed contactor switch by placing an "X" in the appropriate blanks.

   _____a. Mounted to the tachometer drive

   _____b. When the engine overspeeds, the contact points open and send a signal to the shut-off solenoid

   _____c. If the overspeed contactor switch is not activated, it will have to be reset

5. Complete the following list of the functions of the pressure switch.

   a. Used in automatic start-stop system

   b. De-energizes the rack solenoid after______________________________

   ____

6. Arrange in order the operation of the oil pressure and water temperature shut-off switches by placing the correct sequence number in the appropriate blank.

   _____a. The oil pressure switch senses the drop in oil pressure and signals the shut-off solenoid, which shuts off the engine

   _____b. Pressurized oil then flows through line #5 to the water temperature shut-off valve #6

   _____c. Pressurized oil enters line #1 from the auxiliary oil manifold #2

   _____d. The oil then flows behind the control piston in the oil pressure and overspeed shut-off control #3

   _____e. When the engine reaches too high a temperature, the valve opens and dumps the oil back into the oil pan

7. Select true statements concerning the oil pressure contactor switch by placing an "X" in the appropriate blanks.

   _____a. Is an electric switch

   _____b. Signals the shut-off solenoid

   _____c. On automatic start-stop systems, a double set of contacts closes to disconnect the starter solenoid

8. Complete a list of statements concerning the operation of an alarm system.

   a. Uses a light in dash to warn driver of ______________________________

   b. Uses a horn to warn driver of system failure

   c. Has to be reset after ______________________________

9. Demonstrate the ability to:

   a. Troubleshoot the contactor switch for water temperature.

   b. Test a shut-off and alarm system.

   (NOTE: If these activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

EMERGENCY SHUT-DOWN CIRCUITS
UNIT IX

ANSWERS TO TEST

1. a. 4
   b. 9
   c. 5
   d. 1
   e. 6
   f. 7
   g. 2
   h. 10
   i. 3
   j. 8
2. a. Uses a coolant temperature contactor switch
   b. Works in conjunction with a shut-off solenoid
   c. Can be used with oil pressure switch
3. a, c
4. a
5. b. Engine shut-down
6. a. 5
   b. 3
   c. 1
   d. 2
   e. 4
7. a, b
8. a. System failure
   c. Engine has been stopped
9. Performance skills evaluated to the satisfaction of the instructor